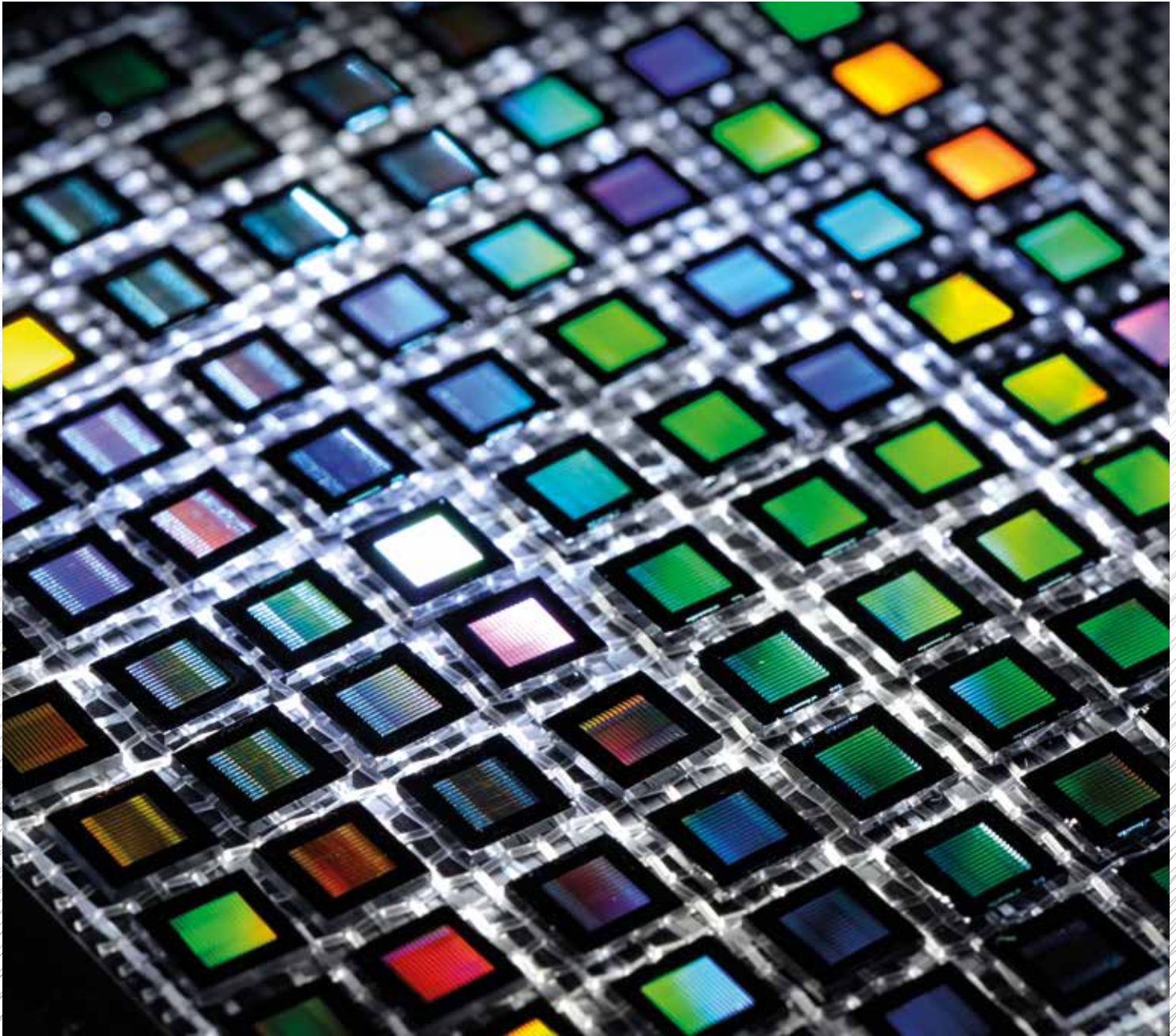


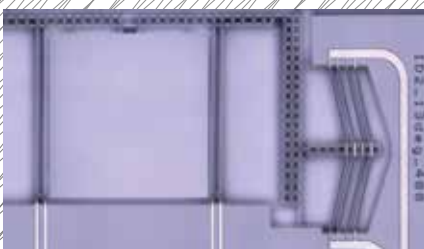
DSPE MIKRONIEK

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PROFESSIONAL JOURNAL ON **PRECISION ENGINEERING**



- **THEME: PRECISION TALENT** ■ **RECONFIGURABLE MECHANISMS & ROBOTS**
- **ON-CHIP MEMS** FOR PHOTONIC FINE-ALIGNMENT ■ **PRECISION IN AM**



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Professional journal on precision engineering and the official organ of DSPE, the Dutch Society for Precision Engineering. Mikroniek provides current information about scientific, technical and business developments in the fields of precision engineering, mechatronics and optics.

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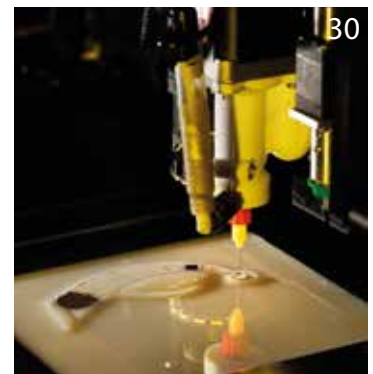
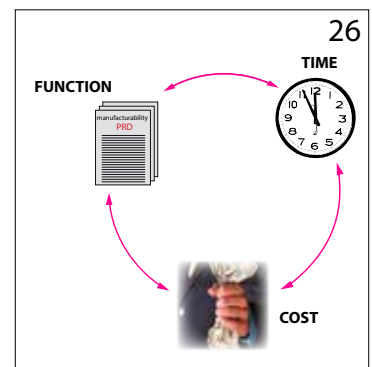
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PRECISION TALENT IN DEMAND

The phrase 'precision talent' immediately triggers thoughts of micrometers and nanometers, the accuracies that are common in sectors such as semicon and space. This is what the Dutch high-tech community excels in and I am proud to be a part of it. But you can also interpret precision talent differently, namely as designing something that is precisely correct, that exactly meets the specifications and is able to be manufactured at a reasonable cost price. The latter is underexposed in semicon and space, where the highest precision performance comes first. It is important to keep this in mind when reading Mikroniek, as this publication deals mainly with extreme precision.

In 1985, I graduated as a mechanical engineer in *Vervoerstechniek* (automotive engineering). At Océ I learned how to develop copiers and printers. Paper handling was designed with pragmatic knowledge; one could see what was happening. In printheads, micrometers were relevant. Copies and prints were judged using a simple loupe. Once I began working for TMC and now for Demcon, I got in touch with 'precision engineering', the domain of micrometers and nanometers.

Are the 'precision' engineers in semicon and space different from the engineers I worked with at Océ? I think the answer is 'no'. Many engineers who had their first working experience at Océ prove it by being successful in semicon projects in the Eindhoven region. Although they had to learn that precision engineering is quite unforgiving: all system aspects such as degrees of freedom, temperature, dynamics, control, etc. have to be taken into account. Even verifying the performance of such nanometer-accurate systems is becoming a challenge in itself. For engineering talents, it is simply an interesting domain with many technical challenges.

In my more than 20 years of experience with recruiting and developing engineering talent, I have learned that the majority is not attracted only to the technical domain he or she is working in. Certainly the ones who are a sort of 'engineer for life' are energised by solving any technical design challenge. And more importantly, they want the 'freedom to operate': the autonomy to make their own choices. This means even room for making mistakes and the chance to solve them their way, knowing that experienced engineers are nearby and available for consultation and mentoring.

The main challenge today is educating and developing mechanical designers. 'System engineering' sounds sexier than mechanical design; and biomedical engineering is attractive to female student engineers. These student ambitions seduce universities into thinking as marketers. I do think it is important to develop the discipline of system engineering, and Dutch engineers even excel in system engineering. However, a unique high-performance system is built upon deep and solid knowledge of disciplines like mechanical, electrical, software and control engineering, physics, etc. To graduates who have been trained in mechatronics, I'd like to say: "Now first learn a proper discipline, then move on and develop your (precision) talent."

Precision engineering is in need of more high-level mechanical designers. So let us, as well as emphasising system thinking, identify and honour the new role models that show student engineers the beauty of a creative single-discipline solution.

Toon Hermans

*Managing director Demcon Eindhoven, DSPE board member
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(Photo: Jan Pasman)

REFLECTIONS ON SYSTEM ARCHITECTING

A system architecture, according to Wikipedia, is the conceptual model that defines structure, behaviour and other aspects (or ‘views’) of a system. Such a model can be used to guide the design of a system and determine its success. In the precision engineering and mechatronics domain, where systems can be very complex, system architecting, i.e., the art of defining and maintaining a system architecture, is a crucial discipline. Ger Schoeber, manager Innovation & Technology at Hotraco and course leader of the famous “System architecting” training course, presents some reflections on this very special (precision) talent.

The pioneer in the field of system architecting, at least from the Dutch perspective, is Gerrit Muller, who has worked at Philips Medical Systems, Philips Research and ASML and is now a research fellow at TNO and a professor in systems engineering in Norway. On the basis of his own experience as a system architect, he developed the so-called CAFCR method (Figure 1), which employs five ‘views’: Customer Objectives, Application, Functional, Conceptual, and Realization [1].

The method provides the structure for an iterative process in which a chain of questions has to be answered: Who is the customer? What is his application? What is the function of the product in the application? With what concept(s) can this be achieved? Is this concept feasible? What are the constraints? Are there new opportunities? [2]

Definition

Muller used the CAFCR method as the foundation for a new training course, called Sysarch (“System architecting”),

which was launched around 2000. In 2002, Ger Schoeber (Figure 2) joined as a teacher and he has now been the acting course leader for many years. On the course provider’s site [3] a clear definition is given: “System architecting is the art and science of designing and building multi-disciplinary systems. The responsibility and the challenge for the system architect is to translate the requirements of the many stakeholders into a system architecture blueprint. He/she will do this based on a solid knowledge of the problem domain, the business context, the human context, the solution domain, technology roadmaps and preceding architectures. The system architect provides the vision, develops the outline for an integral design, keeps the overview and takes care of the design consistency. He/she provides the context for the development activities that will be carried out by large multi-disciplinary teams of specialists.”

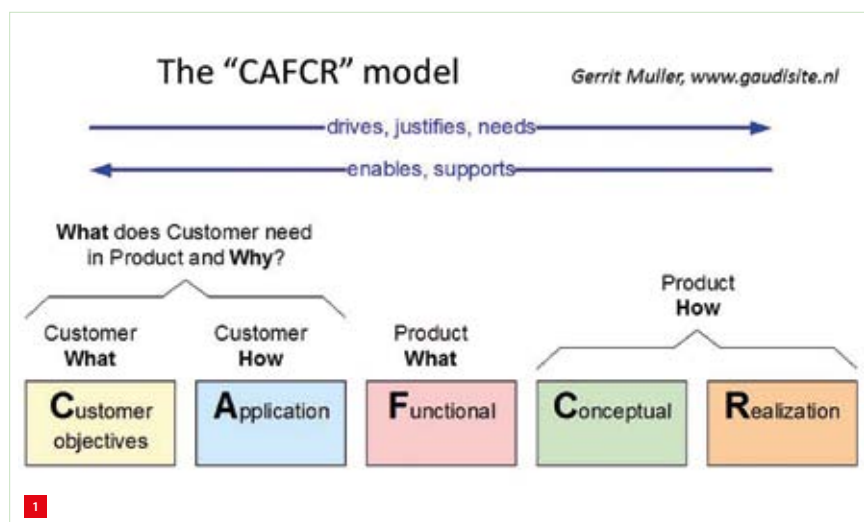
Three roles

It is clear that technology is important, but it is ill-advised to make a one-track-minded, technology-driven engineer the system architect in a design project. Communication skills and business sense are essential ‘tools’ for a system architect, as well as extensive experience. There is a training course, but system architecting is first and foremost learned in practice, hence a system architect is usually a senior professional.

To further outline the scope, Schoeber defines the three leading roles in a technically complex design project:

- the project leader, who is in charge of project planning and resources (people, money, tools, ...);
- the product manager, who is in charge of establishing market demand for a new product/system;
- the system architect, who is in charge of translating market demand into technical system requirements and making an estimation of the project resources required.

1 The CAFCR method.





2

In theory, one and the same person can fulfil these three roles, but it is best when three people each assume one role. Not only does this prevent work overload, also the tensions between potentially conflicting interests that are inherent to any complex project are explicitly represented. Each interest has its own representative and the discussions between them can lead to a well-balanced, optimal project result.

Responsibilities

From the above it is evident that the 'duties' of a system architect are numerous. Among them is requirements engineering, formulating the technical requirements in a 'smart' manner: specific, measurable, achievable, relevant and time-bound. This is the basis for any successful design project. Manufacturability is also the architect's responsibility; this concerns production technologies, materials, cost price, lead time, etc.; see also the article on Design for Manufacturing in this issue (page 26 ff).

Another important aspect of architecting is roadmapping. Choices made regarding the architecture have to be consistent with existing technological and business roadmaps for product (families). On the other hand, these choices can be guiding for new roadmap formulations, so the (future) roadmap always has to be at the back of the architect's mind.

Best of both worlds

Whereas architecting is a common phrase in the high-tech domain system, other domains, such as civil engineering, work with system engineering. There are overlaps and differences between the two terms, related to the complexity of projects from either the technical, business or organisational perspective. In all cases, the ultimate challenge is the same: delivering a sound technical system that is of value to the company and the market.

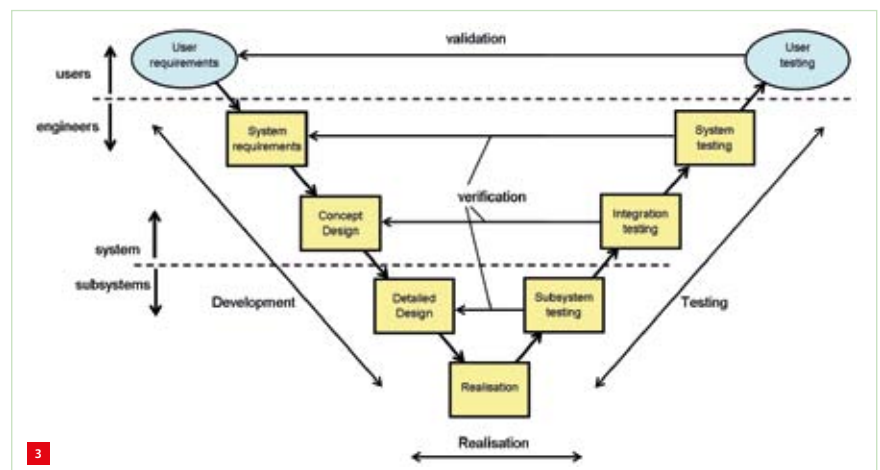
In system engineering, the emphasis is often on process and stakeholder management. As a consequence, losing focus on the technical aspects may introduce risks in the final design. On the other hand, in the high-tech domain the main concerns are often technical complexity and time-to-market. This induces a pragmatic way of working in which the careful execution of the project plan receives less attention. According to Ger Schoeber, however, it is possible to merge the system engineering and system architecting approaches and combine the best of both worlds.

V-model vs Agile

The adage 'best of both worlds' also applies to the methods and tools used in system architecting [2], such as the above-mentioned CAFCR method. This is best illustrated by looking at two 'extremes', the V-model and Agile.

The V-model is a well-structured method, originally devised for hardware-dominated product development (Figure 3). A linear trajectory is followed from the upper left arm of the V (user requirements definition) through various (sub)system development stages to ultimately user testing. A forte of the V-model is that specification and verification are 'automatically' linked to one another at every development level, assuring a design that satisfies the requirements. However, this linear progression is a time-consuming procedure, especially if in later stages design problems or last-minute requirement changes necessitate a redesign in a previous stage.

Here the Agile method (Figure 4), originating from the domain of software development, [7] comes in with its project 'sprints'. A sprint is a short design iteration in which part of the functionality is developed, starting with the critical parts of the design, to create a so-called minimum viable product for which feasibility can be demonstrated at an early stage. This reduces the risk of extensive reiterations at later stages and in subsequent sprints new functionality can be added, building upon the proven core design.

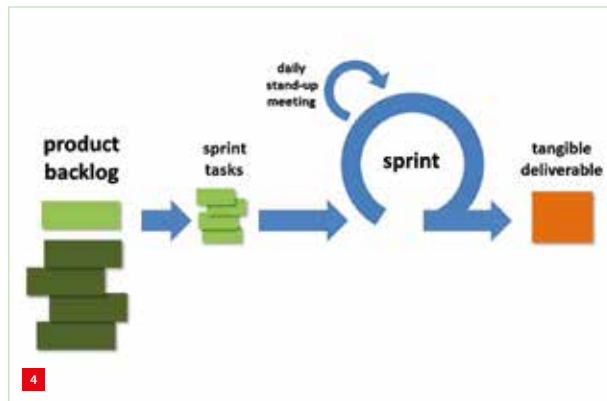


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2 Ger Schoeber is manager Innovation & Technology at Hotraco [4] and course leader of the "System architecting" training course. He is a board member of INCOSE-NL [5], the Dutch branch of the International Council on Systems Engineering, and a steering group member of the System Architecture Study Group (SASG) [6].

3 The V-model [2]; see the text for further explanation.

4 The sprint-based Agile method [7]; see the text for further explanation.



Now it is the architect's mission to combine the two development 'cultures': the long-term goal orientation of the V-model with the short-term flexibility and development speed of Agile. Schoeber envisions a V-model in which at any given moment in time different parts of a design are each at different stages of their development trajectory: when some parts are still at the concept phase, other parts are already at the detailed design phase. Here the so-called student syndrome, i.e. doing the easy bits first to postpone a difficult assignment, should be avoided, Schoeber warns. It is essential to deal with the critical design challenges first.

Interface

Finally, talking about 'worlds', there is another cultural dimension at play. The high-tech community in the Netherlands is adept in system architecting, Ger Schoeber states, partly due to the Dutch 'polder' mentality, combining pragmatism and innovativity. Other countries/cultures, where for example hierarchy is held in high esteem, are better at process planning, sticking to the plan and delivering what was ordered, but have problems dealing with new insights or developments and adjusting plans. Here lies a real challenge for large multi-site, multinational projects and a new role for the system architect, that of cultural interface within a project team. ■

REFERENCES

- [1] www.gaudisite.nl
- [2] R. Zwikker and J. Gunsing, "Merging Process Structure and Design Freedom", *Mikroniek*, vol. 55 (2), pp. 5-13, 2015.
- [3] www.hightechinstitute.nl/en/training/system/training_system_architecting
- [4] www.hotraco-group.com
- [5] www.incose.nl
- [6] www.esi.nl/innovation-support/sharing-know-how/sasg
- [7] [en.wikipedia.org/wiki/Scrum_\(software_development\)](https://en.wikipedia.org/wiki/Scrum_(software_development))

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COMBINING PRACTICAL EXPERIENCE WITH UP-TO-DATE KNOWLEDGE

AUTHOR'S NOTE

After completing his studies in solid-state chemistry, René Raaijmakers began working as a technology journalist in 1989. That role soon provided him with a link to the Philips NatLab and in the nineties he covered the research at this Philips lab for the scientific supplement in the NRC Handelsblad. In 1999, he started Bits&Chips and eight years later, Mechatronica&Machinebouw. He has also written books on the NatLab and ASML. Since 2011, in addition to his publishing firm Techwatch, he has also been managing High Tech Institute.

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When Philips made the decision to spin out the training courses from its former Centre for Technical Training, it was with the explicit intention that this specialist knowledge remained in the Netherlands. The result of this decision was a unique partnership: High Tech Institute. In a personal contribution, the institute's managing director René Raaijmakers offers a status update and outlines the institute's vision and ambitions for technical post-academic education.

RENÉ RAAIJMAKERS

Philips heritage

Seven years ago, the renowned technical training courses of the Philips Centre for Technical Training (CTT) moved to High Tech Institute. When spinning out these course activities in 2011, Philips explicitly expressed that they wished for this knowledge to be retained for the Dutch high-tech ecosystem. So, what is this heritage and what is on the horizon?

For decades, researchers from the illustrious Philips NatLab (Philips Physics Laboratory, commonly denoted as Philips Research) and the Philips Centre for Manufacturing

Technology (CFT) developed training courses for Philips CTT. The customers for these courses were the worldwide R&D departments within Philips's product divisions. The internal training institute was primarily intended to train people in state-of-the-art technology and soft skills.

Top researchers and engineers from the NatLab and CFT – always working on the latest technical possibilities and insights – immediately passed on their knowledge to the product developers. In its peak years, Philips CTT had a portfolio of nearly 100 specialised training courses in IC technology, mechanics, mechatronics, optics, systems,

1 This site, currently the High Tech Campus Eindhoven, became home of the Philips NatLab in the early 1960s, and hence, since 1990, of the Philips Centre for Technical Training. (Source: www.hightechcampus.com)



Philips Centre for Technical Training

Philips CTT was formed in 1990, shortly after Operation Centurion (a major Philips reorganisation). The training institute was set up for R&D for Philips worldwide and was organisationally housed at the NatLab. Most of the teachers were NatLab employees, but from the beginning CTT also provided trainers. The product divisions gradually started to supply more and more teachers.

R&D departments from other companies started to appreciate the unique portfolio of the courses at the centre and increasingly CTT began to receive requests from external parties to open up its training for their technical engineers. Philips reluctantly gave approval, but made two stipulations: external customers paid higher course fees and access was limited to those training sessions that did not contain confidential Philips knowledge.

Despite this, the external influx increased, also as parts of Philips were split off. Courses with confidential information were gradually converted so that eventually all training sessions were open to interested parties outside the group.

Reducing confidentiality proved to be an important development in CTT playing a major role in the regional ecosystem. The later initiative to spin out CTT was partly motivated by the need for an independent training institute outside Philips.

software and innovation. In the boom years of the nineties, it achieved a turnover of more than eight million guilders and between four and five thousand students went through the mill every year.

From the end of the nineties, with the splitting off of numerous activities, Philips CTT's customer base shifted more and more to external parties, subsidiaries and spin-offs (see the box). One major impact was the splitting off of Philips Semiconductors, which in some years had accounted for more than half of all the participation in CTT training courses. In 2004, Philips sold the last remaining ASML shares and, a few years later, Semiconductors continued as NXP. With this departure of her daughters, the mother found this question increasingly important: what do we do with our technical training? It was obvious that they needed to split off this non-core activity. The crisis of 2008 accelerated that.

Through one of the CTT programme managers, I learned that the training activities were for sale. For me it was a simple calculation. I owned a publishing house, Techwatch, which reached a great many highly skilled technical engineers in Belgium and the Netherlands through the publications *Bits&Chips* and *Mechatronica&Machinebouw*. We would be able to use these media platforms to deliver high-end technical training courses.

In the autumn of 2008, I approached deputy director Theun Baller, the man who was responsible for Philips CTT at Philips Research (now Dean of Mechanical Engineering at TU Delft). I visited him together with an advisor and

potential investor from the world of technical training. After all, my own company Techwatch was tiny – I certainly realised that I could not pay for an activity such as a training institute out of my own pocket.

However, Baller had no interest in the financial side of the case. My business partner and I had the illusion that a conclusive business case would be convincing. We argued that we could reach the entire industry via the Techwatch media and thus secure a healthy financial future for the CTT portfolio. In our view, the Brainport high-tech community would automatically benefit from a good business model and a solid financial basis. Baller was not impressed by those arguments.

Baller wanted to hear something different. How would we maintain the quality? How would we ensure that the Eindhoven ecosystem would benefit in particular? Frankly, at that moment I did not realise what the real challenge was: namely, to maintain and renew 50 training courses. If the Philips experts would be contributing less in the long run, where would the content come from? When I said my farewells, I felt that I had not made a sufficiently good impression. After a few weeks, Baller's unsurprising phone call came: sorry, but you didn't get the contract.

New initiative

More than a year later, Philips came up with the solution itself. The CTT activities were placed with Eindhoven parties that were able to keep the training courses up to date. That was the signal for me to start a conversation with these parties, many of whom I already knew. That led, in 2011, to the establishment of High Tech Institute. This organisation went on to take care of marketing and sales in close cooperation with Techwatch. High Tech Institute became the public face of the courses.

The formula is pretty simple. Four content partners manage the content of the training courses, each partner having its own specialties (see the box on the next page). They are responsible for the selection of and the relationship with the teachers, the quality and content of the training, and for keeping the material up to date. The marketing and sales organisation has agreements with each of these four parties on the basis of mutual exclusivity.

Last year, High Tech Institute and Techwatch became full sisters. Both companies have a common denominator in their missions to make independent information and knowledge available to the entire high-tech industry.

As the founder of *Bits&Chips*, I am deeply convinced that an independent professional press contributes to the health of the entire industry, just as an independent press and freedom of expression keep our society and democracy

Partners in the High Tech Institute consortium

- High Tech Institute
Marketing and sales organisation, external representation
- Mechatronics Academy
Coherent training portfolio for precision mechatronics
- Systems & Software Academy
Training portfolio for high-tech systems and software
- Settels Savenije Friedrich
Training in communication and leadership for technical engineers and managers
- T2Prof
Coherent training portfolio for electronics, optics and innovation in high tech
- Techwatch
Sister organisation of High Tech Institute with the Bits&Chips and Mechatronica&Machinebouw publications

healthy. This can also be seen working in the opposite direction: that the high-tech industry is a mature ecosystem is evidenced by the fact that magazines such as *Bits&Chips*, *Mechatronica&Machinebouw* and also *Mikroniek* and *Link Magazine* meet a need in this market.

High Tech Institute's mission is in the same line. The high-quality training courses from our content partners are accessible to everyone and keep the entire high-tech industry vital. We draw on the knowledge of universities and research institutes, and provide lessons learned from practical experience to the entire industry. This helps to keep the Netherlands one of the world's most competitive technology regions.

Portfolio quality

Both High Tech Institute itself and our content partners care deeply about Baller's ideal of keeping the high-quality knowledge of the courses up to date. Content partner Mechatronics Academy, for example, recently gave a thorough update to its 'Design Principles for Precision Engineering' training course (see page 19 ff). This course was fully booked from its release – a sign that the right choices were made in the training programme.

Our partners can respond quickly to developments because they can call on a hundred or so involved trainers. Their experience and the lessons they have learned over the course of their careers are, in my opinion, our greatest added value. I particularly like the fact that many of our trainers have earned their spurs in the development of products that have changed the world, such as the CD player or the wafer stepper. For most of them, transferring knowledge to future generations is a way of life.

In terms of technology and science, knowledge remains up to date because leading researchers and university lecturers are involved. Many of our training courses are continuously fed by the latest insights from the universities of Delft, Eindhoven and Twente.

Due to the proactive attitude of our content partners, we have been able to launch several new training courses in relevant areas over recent years, such as "Thermal Effects in Mechatronic Systems" and "Design for Additive Manufacturing". The course "EMC for motion systems" is in the pipeline and we will be putting it on the agenda soon. As Adrian Rankers of Mechatronics Academy says, "We look carefully at which areas need more knowledge, where we can acquire the relevant knowledge and how we should develop it for our community."

When we started in 2011, we aimed to reach other high-tech players and high-tech suppliers with the CTT portfolio of training courses. This has been very successful. In 2011 and 2012, for example, the course participants in the system architecture training came mainly from Philips and NXP. Now, the attendance nearly always represents as many companies as there are participants. This also applies to most of our mechatronics and electronics training courses.

The highly specialised optics course mainly attracts people from ASML. On the one hand, this ensures continuity, but we want to spread this knowledge to a larger target group. That is why our content partner for optics, T2Prof, is currently working intensively with the Dutch Optics Centre (see age 48).

Practice and exercise

I had a nice experience with a course myself last summer, doing the Basic Course Tree Climbing at The Treeclimbing Company (TTC). I wanted to be able to climb a tree, because I recently bought a house with a small wood. I did not realise that there was so much involved in climbing a



2 The similarities between a Treeclimbing Company training and the High Tech Institute training courses are striking: practice, practice, practice. (Source: thetreeclimbingcompany.com)

tree safely. However, it is telling that they take no less than two days for the beginners' course at TTC. It turned out to be a source of inspiration, and the similarities with the High Tech Institute training courses were striking.

What can you do after two days of tree-climbing training? Very simple: you can gain access to the tree. That is to say, you learn to attach a climbing rope from the ground to the crown and to safely climb up and down. There is a great deal of emphasis on safety; after all, you only die once. The essential point is that after those two days I could dream the whole procedure with all its safety aspects. "I can get you into the tree easily within an hour," said TTC trainer Mark Jakobs, "but then you will not know anything and you will not be able to do it yourself at home tomorrow."

In fact, that is also the essence of the technical and leadership training at High Tech Institute. Almost more than half of a course consists of practice and exercise. When participants arrive at work the following day, they are immediately able to apply their new knowledge. With social skills courses such as "Leadership for technicians and architects", up to 80 per cent of the course is exercises. We realise that practice takes a lot of time. Here we use as the point of departure: it is better to provide training in fewer subjects that will then stick 100 per cent, than to cover as much ground as possible, knowing that most knowledge evaporates quickly.

Jaco Friedrich, a trainer in communication and social skills from content partner Settels Savenije Friedrich, says, "We practise until people really have the hang of it. Experience shows that it is better to really live through a small number of situations than to rush through a lot of them. You will gain nothing at all with theory-only training."

The same applies to many of our technical training courses. Take the three-day "Advanced Feedforward Control". In this course, students work on a control for a printhead. There is a lot of mathematics and software involved, but participants eventually have to put it in a working application themselves. "We want them to apply it fully once and see what it delivers," says Tom Oomen, who teaches this course and is an associate professor at Eindhoven University of Technology. "They take home the algorithm and the software. With these two ingredients they can get started at work immediately."

Investment

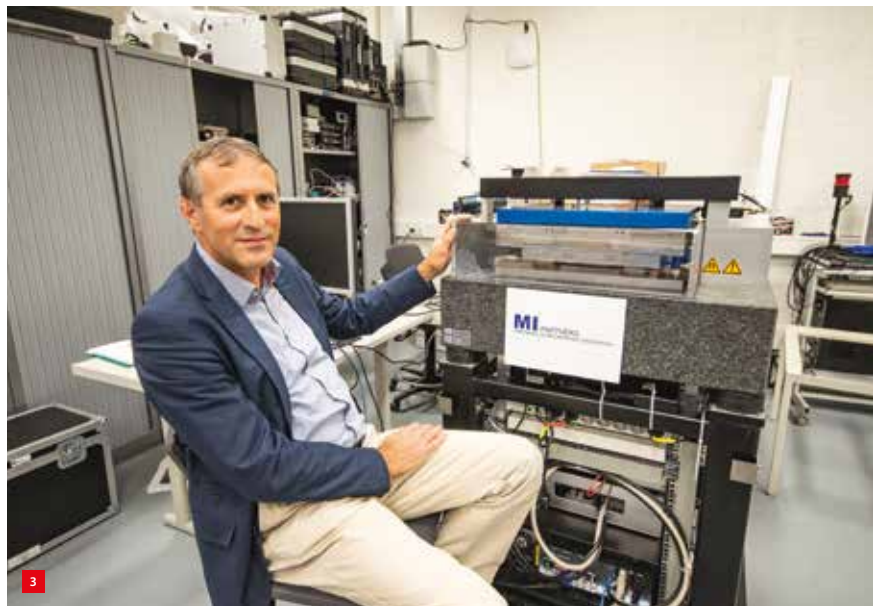
The rise in attention paid to online courses a few years ago eclipsed that paid to hands-on training. We believe that online access to knowledge is very useful and we will

definitely be using this approach in the future. We feel, however, that online is primarily a resource centre, mostly useful as good preparation for the actual course – similar to textbooks, audio and video. The effectiveness of a course in which participants learn the substance by actually applying it and where trainers are ready to give immediate feedback is unrivalled by any other method.

Yes, this kind of study takes time and that also involves an investment. The financial cost of the course is not even the primary issue: in an industry that is dictated by deadlines, multi-day training courses weigh heavily on the available time of employees.

But that investment is worth it. "If you send someone to a course, you lose a piece of turnover", says Jan van Eijk, partner at Mechatronics Academy. After training, however, he says that what you get back is someone who needs fewer hours to complete a job. "He or she also delivers a better design. I assert that if someone does a course at High Tech Institute, they will achieve a five per cent higher return in the five years that follow." Even that, he adds, is still a conservative estimate. "A course takes a week, and that is about two per cent of a year, but you will benefit from that for years."

3 Investment in training is worthwhile, according to Jan van Eijk, partner at Mechatronics Academy, and former former CTO of Mechatronics at Philips Applied Technologies and Emeritus Professor of Advanced Mechatronics at Delft University of Technology: "After training, an engineer delivers a better design, in fewer hours. I assert they will achieve a five per cent higher return in the five years that follow."



Outlook

High Tech Institute has been accepting participants from abroad for years, but the number of in-company training courses is also increasing. Meanwhile, we organise annual courses for companies in Germany, Taiwan and the USA. Techwatch is also currently preparing to boost its international marketing: we are in the advanced stages of publishing *Bits&Chips* online in English, something that goes hand in hand with Techwatch's customers' desire for more international exposure. ■



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FREE INFORMATION, PRICELESS PROMOTION

The Dutch high-tech industry is characterised by a strong collaboration between the various parties that are active in the field. This creates a huge pool of engineering experience that can serve as an accelerator for global business opportunities. Janssen Precision Engineering (JPE), being part of the Dutch high-tech industry for more than 25 years, has demonstrated this global outreach through their Precision Point platform. This has contributed to establishing JPE's worldwide position as an expert in precision engineering.

ROBIN TRINES

Introduction

As precision engineers we all have a certain skill set, or toolbox, filled with tools we use on a daily basis: conceptual designs, mechanical or thermal material properties, stiffness equations, and so on. The contents of this toolbox are unique for every engineer and based on experience. In combination with the typical introvert and problem-solving attitude of the average engineer this leads to reinventing the wheel over and over again. This is of course not effective when looking from a broader perspective.

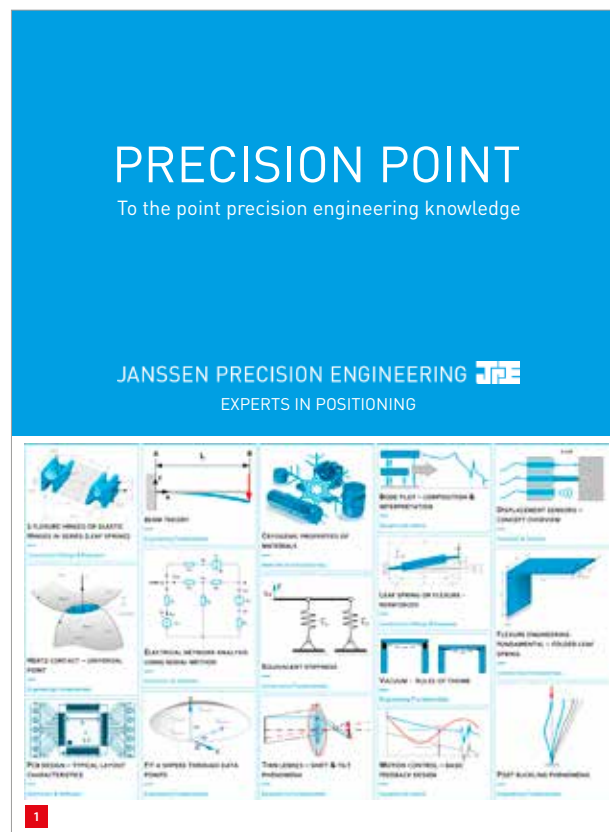
Therefore, JPE attempts to facilitate a more effective use of existing knowledge with the Precision Point platform. It is a database for precision engineering knowledge, which consists of separate sheets, each summarising an engineering topic on one A4 page. The sheets are organised into various categories, such as 'Materials & Manufacturing', 'Construction Design & Examples', and 'Dynamics & Control'. They are often accompanied by calculation sheets for Mathcad or Matlab, which can be used to directly apply the theory. The Precision Point sheets have been collected in a booklet (Figure 1), which can be ordered on the JPE website for a small administrative fee or picked up for free at a JPE stand at fairs. Additionally, all sheets are available as free downloads on the website.

The idea for Precision Point originated at the JPE office in 2012. During projects, the solutions developed lead to technical knowledge, which the JPE team members typically either remember by heart or write down for personal use. By summarising and sharing this information, the whole JPE team could suddenly benefit from all the knowledge gathered over the years, making the engineering process more efficient and effective. With each new project, new challenges arose. The solutions were documented in new Precision Point sheets, expanding the database to its current size. In 2013, the database was made public so that engineers outside of JPE could also benefit from the collected knowledge. The database currently provides information on over 50 topics, with many more in the works.

Added value

"Why would you give your knowledge away for free?" is a question regularly asked. The answer is simple: when we share our knowledge, everyone benefits. Not only engineers

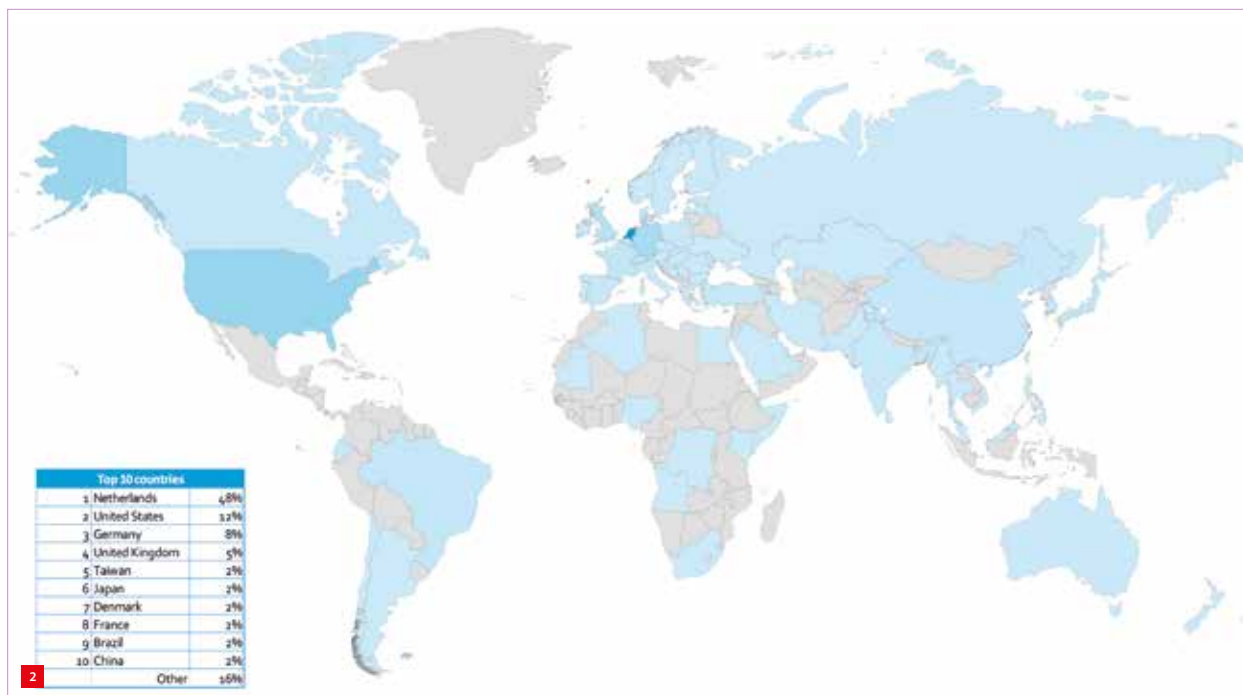
1 The Precision Point booklet cover.



AUTHOR'S NOTE

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2 In 2017, worldwide interest in JPE's Precision Point website amounted to a total of 13,500 visitors. The legend presents the top ten countries of origin. The more visits a country generated, the darker blue it is depicted in the map.

and students who read the booklets or download sheets. For JPE, the platform generates a significant amount of traffic to the company's website from visitors around the world (see Figure 2). Many of these people later visit pages about JPE's high-tech engineering services and cryo-/nano-products. On fairs and conferences the Precision Point booklets are always in high demand.

Therefore, the added value for JPE mainly lies in the Precision Point functioning as an effective marketing tool and a way to expand the network outside the Netherlands. The generated extra business also benefits JPE's suppliers and subcontractors and introduces customers from around the world to the Dutch high-tech ecosystem. Additionally, we learn from readers contacting us with errors they spot or alternative insights they want to share.

Although it is true that technically we are also making our competitors smarter, this is not a downside. The added value that we as an engineering company provide for our customers does not lie in the information itself, but rather in the skill of transforming that information into practical solutions to their challenges.

In the end, a lot of the information on Precision Point is already publicly available. It is general knowledge, but now structured and organised in such a way that it is accessible and easy to use. The Dutch high-tech industry is known for its collaborative rather than competitive nature. This is arguably one of the reasons why it is so successful globally. Something which JPE recognises and wants to contribute to, through Precision Point.

Precision talent

The platform is also very popular amongst students, who use it partly as a reference book and partly to familiarise themselves with topics that are not taught in-depth during their studies. Some teachers even provide the booklets to their engineering classes as supplementary reading material, for example professor Alex Slocum at the renowned Massachusetts Institute of Technology (MIT).

In this sense, Precision Point not only helps to make students familiar with the JPE brand, but more generally with high-tech engineering in the Netherlands. In a time where engineering talent is scarce, everyone benefits when we can excite students about precision engineering. When we meet students at events, they often know JPE through Precision Point and are curious to find out more.

Future

For the future, JPE has two main goals with Precision Point. First, to keep expanding the knowledge database with interesting topics that we encounter in new and challenging engineering projects. New sheets are uploaded to the JPE website and announced on the Precision Point LinkedIn page. The booklet will be revised approximately once every two years, with new and updated sheets. Secondly, JPE intends to continue expanding its network and further improve the conversion of the Precision Point platform into business opportunities for JPE and its partners. ■

INFORMATION

WWW.JPE.NL/PRECISIONPOINT

WWW.LINKEDIN.COM/SHOWCASE/JPE-PRECISION-POINT

TAPPING INTO A NEW DSPE MEMBER'S EXPERTISE

Inholland University of Applied Sciences Delft - a unique programme in Precision Engineering

Last year, Inholland University of Applied Sciences Delft started a unique higher professional education programme: Precision Engineering (PE), a specialisation in the Aeronautical Engineering programme. In addition to mathematics and mechanics, PE students learn how to design technical instruments that operate with great precision and reliability. In teams of varying composition, they work on their technical background and design skills in a programme that has a good balance between theory and practice.

INFORMATION

To obtain more information on the new PE B.Sc. programme, or to offer internships, guest lectures or company tours, Philip Weersma can be contacted. The next information evening (17.00-20.00 h) will be on Wednesday 31 October 2018.

PHILIP.WEERSMA@
INHOLLAND.NL
INHOLLAND.NL/PE

The PE programme is designed to meet the rapidly growing demand for highly qualified engineers at the higher professional education level (HBO in Dutch), who can design, create and test high-tech systems, machines and instruments. "Field surveys have revealed an increasing demand for technical specialists who are able to bridge the gap between innovative ideas and their realisation", says Philip Weersma, coordinator of the PE programme. "We started in September 2017 and have just finished the first school year. There are students from different theoretical and/or vocational backgrounds (i.e. HAVO, VWO and MBO levels, as per the Dutch educational system) and we saw them all learning from each other. Developing team skills is an essential part of the programme."

PE skills

Precision Engineering is a four-year B.Sc. differentiation within the Aeronautical Engineering programme. It has its own graduation profile, consisting of two parts: the major and the graduation project. During the first and second years, students work on the basic PE skills, with much time devoted to mathematics, mechanics, electronics, control systems, analytical skills, such as static and dynamic analysis, and

optical techniques. In addition, they develop practical skills by doing various projects and workshop practicals.

Cooperation with the LiS

The theoretical part is almost entirely provided by Inholland University of Applied Sciences – a university offering several B.Sc. programmes in Delft and at other locations in the western Netherlands. The Leiden Instrument Makers School (LiS) provides part of the practicals, including training in processing techniques. In the second year, students learn to operate modern machine tools and instruments in the LiS workshops. In addition, their precision engineering focus is reinforced through theme projects, (guest) lectures and excursions to trade fairs and companies. In the latter part of the programme, the emphasis is more on deepening the precision engineering discipline, for instance with guest lectures by experts from DSPE. "We think it is important for students to develop a good picture of the work environment."

Successful first year

In the third year, the students undertake a 20-week internship at a Dutch high-tech company or university research lab. Lastly, the students complete their study with a graduation project in line with their own interest and ambition (and, of course, complying with the official B.Sc. standards and procedures). In short, the PE programme unites innovation, design, craftsmanship, production and team skills. "We are proud to look back on a successful first year of this unique programme that has been set up by the pioneers Egbert Bol of Inholland and Dick Harms of the LiS, with the help of DSPE and its members."

Target group

The programme is aimed at HAVO and VWO graduates (with the appropriate science/technology profile) and MBO graduates with an interest in technology and a talent for science subjects. "We are looking for inquisitive, critically/analytically versed, solution-oriented, technical talents who would like to learn how to design and realise constructions that achieve an optimal level of precision", Weersma concludes. ■



1 PE students focusing on their team assignment.

Components of the PE programme

- Machines and systems
- Mathematics and mechanics
- Control theory
- Fluid dynamics
- Materials science
- Electronics
- Optical techniques
- Design principles for PE
- Production technology
- Workshop technology
- Communication skills
- Project management
- Design/CAD
- Entrepreneurship

ELEGANCE IN COMPLEXITY

AUTHOR'S NOTE

Joep P.A. Nijssen is a Ph.D. candidate in the Mechatronic System Design (MSD) research group of the Department of Precision and Microsystems Engineering at Delft University of Technology, the Netherlands. For this work he received a nomination for the 2017 Wim van der Hoek Award. The research presented is part of a collaborative research project together with Giuseppe Radaelli (Ph.D. candidate at MSD), Just L. Herder (chair of MSD research group) and Charles J. Kim (associate professor at Bucknell University, USA).

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For many years engineers have used basic geometrical shapes for various kinetic and kinematic purposes. We are very familiar with beam and tube geometries applied in flexure applications ranging from mechanisms to high-performance precision machines. There are however significantly more complex and intricate shapes in nature and mathematics that have yet to be utilised to their full potential. The challenge is to make them available for designers and make them as easy to design with as their conventional counterparts. This article introduces some principles and discusses the potential in engineering design.

JOEP NIJSSEN

Leafspring flexures can be regarded as the most basic spatial elastic mechanism, having no curvature and having a small geometrical dimension in one direction compared to the others. Their importance in the design of mechanisms is not to be underestimated and their design principles are well known. Their kinematic behaviour is limited, however.

A very logical step would be to add curvature to the flexure such that its kinematic behaviour changes. This can either greatly increase stiffness by creating dome-like structures or create a large source of potentially interesting geometries for (design) engineers to implement. As seen in Figure 1, by adding curvature the flexures can rapidly become complex, which makes understanding their behaviour significantly more difficult than that of the original flexure started with.

The question therefore arises: What kind of shapes will be of interest from an engineering perspective? And, if we have

obtained a number of viable shapes, what is their behaviour and how can we use them in our design challenges?

Flexures as surfaces

Flexures can be looked at as surfaces because they are generally very thin. Surfaces have been investigated in-depth in the field of mathematics. If we are interested in more complex flexure geometries, it therefore makes sense to look into the relevant mathematical surface libraries. These libraries can inspire mechanism designers to come up with flexure geometries that are increasingly more difficult in form and function. The advantage of these mathematical shapes is that compared to free-formed flexures, there is still a mathematical description that we can use in the modelling and eventual fabrication of the flexures. We can have very complex shapes, which can actually be described very elegantly by a set of surface equations [1]. Examples can be seen in Figure 2.

There are also more complex methods of modelling these geometries and sometimes the surface equations will provide a starting point for later optimisation. An example is the gravity balancer of Giuseppe Radaelli [2], seen in Figure 3. The shape of the mechanism is a highly unconventional geometry, which has been shape-optimised in order to exhibit a near-zero-stiffness behaviour over a large range of motion. This was made possible by describing the surface in NURBS (non-uniform rational B splines), which is a technique often used in computer graphics to describe complex surfaces.

A comparable method was used in other research where a geometry was chosen from one of these previously mentioned surface libraries. This hyperbolic paraboloid (hypar in short) was optimised using NURBS and shape optimisation to create a flexure capable of having a 40-N force capacity again over a large range of motion. The hypar seen in Figure 4 is used in an orthosis concept that makes

1 Starting from the most basic leafspring flexure on the left, simply by adding additional curvature, we can change the behaviour. In some cases, as with the dome-like flexure on the right, this significantly increases stiffness.

2 Three complex flexure geometries (corrugated helix, shoe surface and crossed helix) that can all be described by a set of surface equations.



3 The gravity balancer designed by Giuseppe Radaelli [2], capable of balancing its own weight over a large range of motion.

4 The optimised hypar which is capable of having a constant-force characteristic over a significant range compared to its own length. The hypar has zero stiffness in the x-direction. The corresponding zero-stiffness behaviour for this flexure is equal to the 40-N curve seen in the force-deflection plot.

5 A wide range of complex flexures and serial and parallel combinations of them. How can we describe the behaviour of these kinds of mechanisms without it becoming too complex? These flexures are all made from polyethylene using thermoforming.

6 The ellipsoid describing the translational freedom range of a helix is seen on the right. The input force sphere F (left) is transformed into the output compliance ellipsoid describing the motion behaviour. The visual representation of the freedom range of the complex shape makes understanding it more tangible.



use of these force generators in order to provide spine correction [3].

Kinematics over kinetics

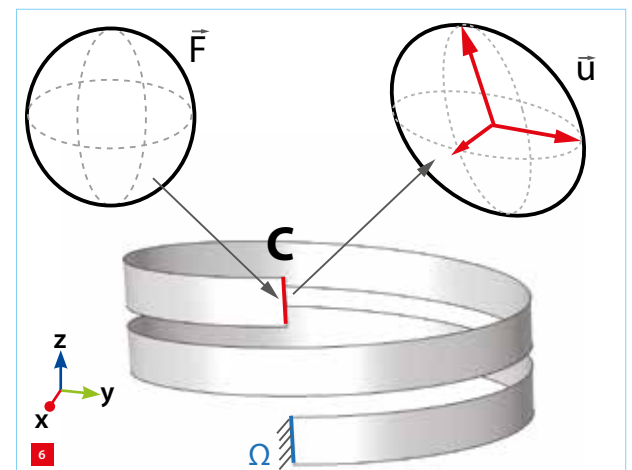
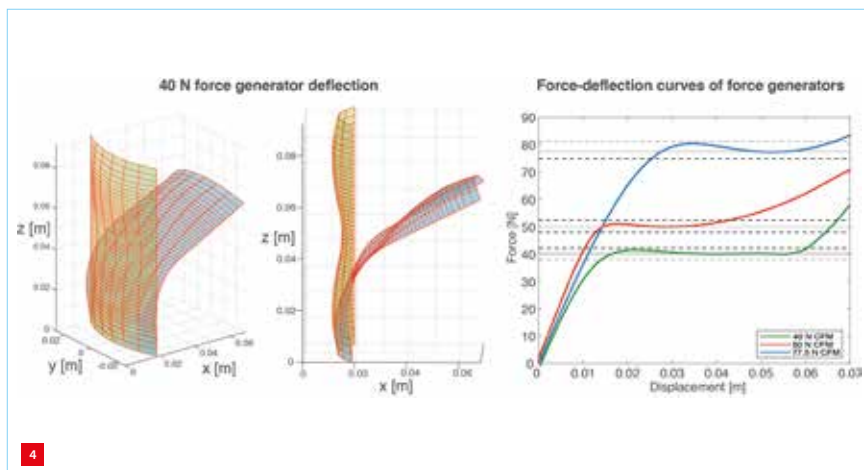
These types of flexures have a clear objective: create a certain force behaviour in a specific direction. Both the gravity balancer and the hypar are 1-DoF force generators (DoF = degree of freedom). Another important design objective that mechanisms are used for is to create a certain motion behaviour. Here another challenge arises: how do we describe the motion behaviour of complex flexures? Having this library of potential flexure shapes is not worth much if an engineer cannot describe how the flexures behave. We preferably want these shapes to be as intuitive as conventional leafspring flexures during concept design.

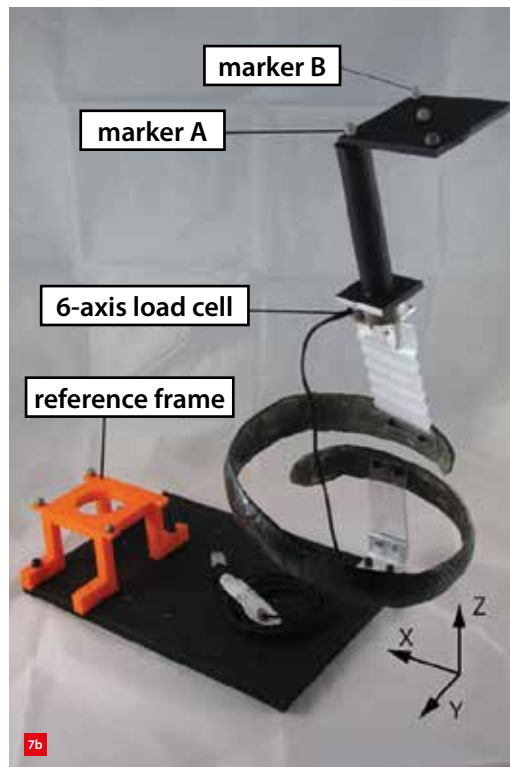
Another challenge is that DoFs at some point lack the information to properly describe the motion behaviour of certain shapes. What works for a leafspring flexure or a set of leafspring flexures might for instance not work for a crossed helix (seen in Figure 5). And what happens if we want to describe the motion behaviour of a set of these complex shapes in a certain configuration?



A possible approach that can be followed is looking at the flexures as separate building blocks and describing the motion of the blocks separately. In the building-block-type synthesis approach, Charles Kim [4] presents the use of so-called compliance ellipsoids. A compliance ellipsoid creates a visual representation of the relative DoFs in three dimensions. By constraining a flexure on one side and actuating it on the other, we can transform a unit force sphere into a displacement ellipsoid. Two ellipsoids are thus needed to describe a three-dimensional mechanism in all its DoFs, one for the rotations and one for the translations. The semi-axes of the ellipsoids present the ratio of motion, which is a more elaborate description of the DoFs.

The ellipsoid of the helix in Figure 6 for instance shows that its largest motion direction is roughly in the z- and y-direction, whereas the allowable motion in the x-direction is more restricted. Two ellipsoids (one rotation and one translation) can thus describe – by means of a visual representation – the linear relative DoFs exhibited by these complex geometries. Especially by having a visual representation, it becomes much more intuitive to use complex flexures in initial concept design. The ellipsoids can also be used to determine the motion profile of serial and parallel conjugated mechanisms, but additional theory is needed to describe the resulting behaviour; it can be found in the work of Charles Kim [4].





7 Design of a flexible orthosis for spinal correction (a scoliosis brace) using the ellipsoid-based approach.

- (a) The design is a combination of flexures made from different materials (including polycarbonate and carbon fibre) in order to obtain the desired properties.
- (b) The motion is made possible by means of a combination of three shell mechanisms connected to a measurement reference frame base. The behaviour of the combination of mechanisms can be validated using motion-capture-based measurement systems (employing the markers indicated) together with load cells to determine the force-deflection behaviour of the complex flexure. The handle on top of the single corrugated shell is used to manually actuate the mechanism.

Spatial mechanisms in design

The method presented allows for an intuitive description of the mechanisms by visually representing their motion behaviour. This is especially valuable in initial stages of design, where the topology is still to be decided by the engineer. An example of where this method proved to be useful was in the design of a flexible orthosis for spinal correction (Figure 7).

In this design example the problem was described using ellipsoids as well, making use of the design method presented in [5]. By having the problem and the possible building blocks in the same representation, the engineer can make a combination of mechanism concepts and investigate the spectrum of possible design solutions. These solutions can then be further developed using finite-element approaches and validated with measurements.

Conclusion

Although there is some basic theory available to describe the behaviour of complex flexures, continuous research efforts are being made. Further theory is currently being developed to more easily describe these complex flexures, not only in their linear, but also in their non-linear behaviour. Joost Leemans [6] has further developed theory based on screw theory in order to gain insight into the large deforming behaviour. Jelle Rommers et al. [7] on the other hand are taking a different approach to come up with spatial flexures of a more discrete geometrical origin that are more focused towards the precision industry.

Another challenge that requires both research and industrial attention is the production of these complex geometries. For exoskeletal and orthosis-like mechanisms, the use of engineering plastics and composites facilitates excellent mouldability. However, material effects like creep and orthotropic material properties might not be suitable for all engineering purposes. The development is ongoing and continues to inspire the design of even more complex and elegant mechanisms. ■

REFERENCES

- [1] Krivoshapko S.N., and Ivanov, V.N., *Encyclopedia of Analytical Surfaces*, Springer, 2015.
- [2] Radaelli G., and Herder, J.L., "Gravity Balanced Compliant Shell Mechanisms", *Int'l. Journal of Solids and Structures*, vol. 118-119, pp. 78-88, 2017.
- [3] Nijssen, J.P.A., Radaelli, G., Herder J.L., Kim, C.J., and Ring, J.B., "Design and Analysis of a Shell Mechanism Based Two-Fold Force Controlled Scoliosis Brace", *Proc. of the IDETC/CIE 2017 ASME International Conference*, DETC2017-67812, 2017.
- [4] Kim, C.J., "A Conceptual Approach to the Computational Synthesis of Compliant Mechanisms", Dissertation, University of Michigan, 2005.
- [5] Nijssen, J.P.A., Radaelli, G., Herder J.L., Kim, C.J., and Ring, J.B., "Spatial Concept Synthesis of Compliant Mechanisms utilizing Non-Linear Eigentwist Characterization", *Proc. of the IDETC/CIE 2018 ASME International Conference*, DETC2018- 85307, 2018.
- [6] J. Leemans, "Characterization of non-linear compliant shell mechanisms: To enhance the design process of a compliant scoliosis brace", M.Sc. thesis, Delft University of Technology, 2018.
- [7] Rommers, J., Naves, M., Brouwer D.M., and Herder, J.L., "A Large Range Spatial Linear Guide With Torsion Reinforcement Structures", *Proc. of the IDETC/CIE 2018 ASME International Conference*, DETC2018- 86424, 2018.

FIRMLY ANCHORED IN WIM VAN DER HOEK'S IDEAS

The Design Principles training course underwent considerably changes this year – in a sense. The foundations laid by the renowned professor Wim van der Hoek, the Dutch doyen of precision engineering, remain a strong anchor. The biggest changes are fresh trainers and a few elements of new material. And also the name: the course is now called “Design Principles for Precision Engineering”.

EDITORIAL NOTE

This article was contributed by High Tech Systems Institute (see also page 8 ff).

www.hightechinstitute.nl

Piet van Rens was the face of the Design Principles training course for years. He remains connected to the course, but Huub Janssen of Janssen Precision Engineering is the new figurehead. The common denominator

between them is that they both come from the school of professor Wim van der Hoek. Last June, the renewed course was run for the first time – with full attendance. In addition to Janssen and Van Rens, other trainers contributing to the course are Chris Werner and Roger Hamelinck from Entechna Engineering in Eindhoven, professor of Precision Engineering Dannis Brouwer from University of Twente, and Kees Verbaan from NTS-Group.

“This reference work, including the improved solutions, became so well known that eventually everyone found it an honour when their design was included”, says Piet van Rens.

New elements

Van der Hoek's successors, the professors Rien Koster and Herman Soemers and associate professor Nick Rosielle, enriched that foundation. “The new-style Design Principles training course builds on the legacy of principally correct design engineering that we have had in the Netherlands for decades”, says course leader Adrian Rankers of Mechatronics Academy, the partner responsible for all mechatronics training courses at High Tech Institute.

There are also new elements, however. The course now places more emphasis on damping and on advanced elastic elements with a somewhat larger stroke. Elastic elements are often limited in their range of motion, but there are concepts that are able to achieve larger strokes. This is one of the research topics addressed by Twente professor Dannis Brouwer, who provides one day of training on flexure mechanisms.

Brouwer also deals with energy compensation and gravity compensation techniques (think of the kitchen cabinets that you can open and close vertically and that stay in position while still moving up and down easily). “That includes balancing mass-like issues”, says Adrian Rankers. “As in a complex robot system, where you try to get rid of the reaction forces on the floor by having another body simultaneously make the right moves to compensate for those forces. That can be complicated, so we called it ‘energy compensation’, but you could also call it ‘energy balancing’.”

Mechatronics

Rankers emphasises that the ‘mechatronic context’ recurs throughout the course. “On the one hand, it provides additional requirements for mechanics; on the other hand,



1 Piet van Rens was the face of the Design Principles training course for years. While he is still teaching, he has reduced his input this year.

Van der Hoek's design method still broadly underpins “Design Principles for Precision Engineering”. In the sixties and seventies, Wim van der Hoek devised a number of essential design principles, such as the famous flexure hinges with which machine builders could achieve nanometer precision. In addition, he wrote a syllabus from which he gained great fame. In Chapter 13 of that syllabus, named *Des Duivels Prentenboek* (The Devil's Picture book), he collected unsuccessful mechanical designs.

2 Course leader Huub Janssen is the new figurehead of the Design Principles training course. The precision engineer honoured Wim van der Hoek by naming the new meeting and demo room at Janssen Precision Engineering after his great inspirer.

it offers an alternative solution space. It used to be that if you created a positioning system, you did that with a cam drive and a drive chain up to the element that you had to position properly. In that chain you came across all kinds of friction and play, all of which was very annoying. In a mechatronic movement system, however, you have sensors on your payload. They say exactly what the position or position error is. In principle, you won't be bothered if there is a bit of friction or play in between, because you already have that information and can immediately compensate. These kinds of trends have shifted the subject focus in the Design Principles training course, although it remains the case that you can never get a high-quality system solution with rattling mechanics”, says Rankers.

“We have cut a bit in the less important topics to make room for the new topics.”

Precision engineering

Course leader Huub Janssen has set himself the goal of structuring Design Principles in the spirit of Van der Hoek. “We are talking about design principles for precision engineering. That is the world of complex machines and instruments for the chip industry, astronomy and space travel. In order to position with accuracy greater than a micrometer, you cannot simply use standard functional elements such as bearings. So you come to elastic elements, without friction and those kind of things. Then it becomes exciting, because then you are very close to the underlying physics.”

Thought experiments

Janssen states that manufacturers must recognise that they cannot buy standard parts from the catalogue. They have to think a bit further, analyse all the problems that may arise. Then they have to do thought experiments: where can things go wrong? Once they can see that, the solution direction is close.

Van der Hoek used to ask his students to do thought experiments, says Janssen. “I still remember Van der Hoek asking us to crawl mentally into a ball bearing, to imagine the outer ring and the inner ring with all the balls in between. We had to make ourselves small enough to sit between those spinning balls. Then you could see that the ball on one side was against the ring, while the other side exhibited play. Then you saw that a ball was not completely round; it had butts and didn't roll nicely. You didn't have to have much experience, but you really needed imagination.”

It is no coincidence that Janssen wants to enrich the training course with experience and exercises. “The solution directions are important. I don't do much with formulas. These are necessary, but calculations are the last ten per cent. Designers especially need to get a feel for the details. What should they pay attention to? How do they solve it? You first need to know where things can go wrong and come up with a good conceptual direction. First of all, I want to instil intuition. The maths comes after that.”

Cases first

To that end, he wants to introduce cases. Van der Hoek did that in his Devil's Picture book, in which he published many failed projects. “Participants have to work on cases on their own and in groups. Then we discuss them in the larger group. I don't want to give a lecture, I want interaction.”



Exercises, interaction and working on practical cases are distinctive elements in the training courses that Mechatronics Academy and High Tech Institute bring to the market. Other course providers also offer the course, but in a three-day variant. "Some clients make the Design Principles course compulsory for secondment. Engineering firms then sometimes opt for the three-day variant on the basis of cost or for a variant that runs in the evenings", says Piet van Rens, who also has experience as a trainer in the three-day course.

He thinks this is a less sensible choice, as participants in the short version really miss something. He feels that exercises are the most valuable components of the Design Principles course. They ensure that the subject matter really sticks and that participants actually understand the content and are able to apply it in their daily work. It is precisely that hands-on element that is killed in the shortened version. "The three-day and evening trainings are not bad, but they rush through the content in a short time. Especially in the evenings after a normal working day, people are tired. If you only 'send' rather than offer exercises, then the result is noticeably less", Van Rens concludes. ■

Topics

The five-day "Design Principles for Precision Engineering" training course covers the following topics:

- The role of stiffness and compliance in mechanisms and how to evaluate these mechanisms
- Controlling degrees of freedom
- Optimal use of elastic elements
- Friction, hysteresis and micro-slip
- Real and virtual play
- How to realise damping
- Balancing manipulators

The training material was originally developed by Prof. Ir. W. van der Hoek (Philips and Eindhoven University of Technology (TU/e) from 1962 until 1984) and Prof. Dr. Ir. M.P. Koster (Philips, TU/e and University of Twente from 1984 until 2008).

PI



∞ possibilities

IN PRECISION MOTION

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BOOSTING EUROPEAN PRECISION TALENT – RATIONALE, RESULTS AND REFLECTION



Within the context of the Europe's "excellence in manufacturing" ambitions, euspen has introduced the ECP² (European Certified Precision Engineering Course Program) short-course assessment standard. The aim of the ECP² is to support continuous professional development in precision engineering from a European perspective, building on DSPE's successful Certified Precision Engineer program. Now, all is in place for a further expansion of the ECP² program.

With the manufacturing sector in the European Union, including the United Kingdom, representing over two million companies, and providing 33 million jobs, it is vital that its future is supported by initiatives that focus on exactly the areas that have been identified as central to success over the coming decades.

Roadmap

The European Factories of the Future Research Association (EFFRA) recently produced a roadmap entitled "Factories 4.0 and Beyond", looking at precisely where emphasis was needed in order to support the EU manufacturing sector, which is responsible for 15% of European-wide GDP, stimulates 80% of Europe's exports, and receives two-thirds of total European investment in R&D.

The roadmap looks at key technologies and enablers for "excellence in manufacturing", with a specific focus on high-precision manufacturing, zero-defect manufacturing, and innovative production technologies. Throughout the EFFRA paper, a central theme runs, and that is the real need to support the human factor in manufacturing scenarios, the requirement being to support training and re-skilling in highly specialised topics.

EFFRA's "Factories 4.0 and Beyond" sees precision engineering as a key competence required for advanced manufacturing, it being needed for advanced product/process engineering in customer-supplier business-to-business interactions. Precision engineering includes both



multidisciplinary study and practice of high-accuracy engineering, metrology, and manufacturing of high-precision machines, instruments, and components.

Euspen initiative

Euspen (the European Society for Precision Engineering and Nanotechnology) is one of Europe's most influential bodies working in the precision engineering space. It draws together a community of industrialists, researchers, and academics all working at the cutting edge of micro- and nanomanufacturing, providing them with an entrepreneurial platform for the development of new and innovative technology solutions.

To support the EFFRA recommendations for multidisciplinary study, euspen has introduced the ECP² (European Certified Precision Engineering Course Program) short-course assessment standard (see the Reflection box, page 30 ff, for DSPE's pioneering role). The ECP² program is an industry-recognised standard providing

1 At the Precision Fair 2015 in Veldhoven, the Netherlands, David Billington, executive director of euspen, (left) and Jan Willem Martens, chairman of the DSPE Certification Program, signed the agreement that officially marked the DSPE-euspen collaboration and the start of the ECP² program. (Photo: Jan Pasman/Mikrocentrum)

EDITORIAL NOTE

The rationale and results were provided by euspen's director, David Billington. The reflection was based on a Mikroniek interview with Jan-Willem Martens.

a structured approach to continuous professional development and training for engineers working within the fields of precision engineering and nanotechnology.

The aim of the ECP² is to support continuous professional development in precision engineering in a European perspective, offering to individuals high-quality learning opportunities for specialised key competences, in order to foster employability and personal development in strategic European industries.

Target groups

Key among the constituency of professionals that the ECP² program caters for are employees in industry who have to keep their skills up-to-date in line with the requirements of the precision engineering sector. Typically, such professionals have attained an engineering degree or gained 'hands-on' experience of precision engineering topics while working. Other groups that could benefit are Ph.D. students and teachers in mechanical and mechatronics-based subjects at institutions that have limited access to advanced courses in precision engineering.

Euspen launched the ECP² program as it understood that there are currently a limited number of adequate training opportunities available in Europe. In addition, learners, course providers and industrial enterprises have difficulty in identifying, evaluating, and selecting courses as well as the documentation of competences. Also, the learning outcomes approach is limited in application to short courses for precision engineering.

Objectives

The ECP² program aims to deliver five key objectives:

- Create a European framework for continuous professional development in precision engineering.
- Define a standardised assessment and evaluation of learning success.
- Establish good practice for new course design, development, and testing.
- Define procedures and a European platform for course management.
- Identify market gaps within training and provide additional training opportunities.

The overall strategy for implementing the ECP² program is centred around the sharing of national and international experience on "excellence in training for precision engineering" as a common and strong basis to design, implement, and test the innovative outputs. The project joins innovation efforts with EU-wide availability of training in precision engineering, including recognition of qualifications and developing common curricula, criteria, and content, to be implemented and tested at different levels.

Outcomes

As a one-point, open-access, integrated platform for learners and teachers, ECP² delivers four key outcomes:

- Learners: (through achievement of certification recognised at a European level) personal development, new skills, improved employability, mobility, and career prospects.
- Participants: new tools and methodology for vocational educational training and certification; new courses/resources for future use and replication; and increased visibility and extended networks for future collaborations.
- Industry: increased innovation capacity with staff possessing certified training, demonstrating quality of learning and applicability of skills gained, and participation in shaping future training.
- Longer-term benefits of recognition and standardisation of precision engineering skills across Europe to allow transnational mobility of skills.

The ECP² is a short-course certification program offering individuals high-quality learning opportunities for specialised key competences, in order to foster employability and personal development in strategic European industries. Short courses are assessed and approved for inclusion within the program by euspen's highly regarded education committee.

First results

So far, just over 2,000 attendees (over 98% of them from industry) have on average completed 1.25 course, so a total of 2,500 course certificates have been issued (in 2017 nearly 300). The top three courses by number of attendees are: "Mechatronics System Design" (part 1 and 2), "System Architecting", and "Applied Optics". Several attendees have already achieved bronze level (25 points); see the Reflection box for an explanation of the points.

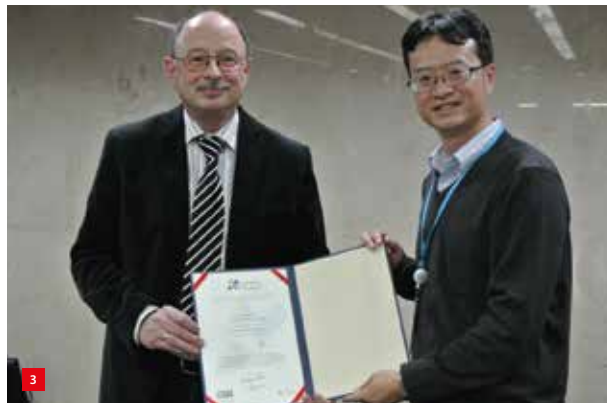


2 In 2015, Nikola Vasiljević (Technical University of Denmark) and Tasja van Rhee (ASML) were the first to reach bronze level in the then CPE-program.

Future

The main push of the program at present is to increase awareness within the UK and Germany to establish a range of courses comparable to the ones available within the Netherlands. The future remodelling of the program will include categorising courses into four main headings and this aims to make course choice even easier for the end user:

1. Fundamentals of precision engineering
2. Manufacturing
3. Mechatronics
4. Metrology



3 In 2016, the ECP²-certified "Mechatronics System Design" training course, provided by Mechatronics Academy through High Tech Institute, was delivered at ITRI (Industrial Technology Research Institute) in Taiwan. The photo shows participant Hsiang-Hung Chang receiving the ECP² certificate from Prof. Rob Munnig Schmidt, one of the course teachers.

Reflection

Euspen's ECP² program originated from DSPE's Certified Precision Engineer (CPE) program, which was developed in the Netherlands in 2008 as a commercially available series of training courses. Inspired by the success of this program, euspen decided in 2015 to take certification to a European level. The resulting ECP² reflects industry demand for multidisciplinary system thinking and an in-depth knowledge of the relevant disciplines.

The ECP² program was based on the DSPE program, which means that all Dutch CPE-certified courses were incorporated into the ECP² scheme, as were the associated points (i.e. credits a student can earn for each course, where 25 points is a bronze level, 35 a silver level and 45 points is gold, recognised with the title ECP² Certified Precision Engineer). In the meantime, courses from British providers have been added; see page 46 for an overview of the current offer.

Jan-Willem Martens, former vice president systems engineering at ASML, was one of the initiators of the CPE program. He acted as chairman of the DSPE Certification Program and now is an advisor to euspen. Looking back at the development of the program and its scale-up by euspen, he says, "I am proud of the structure for certifying precision engineering courses we have set up and the international scope it has now attained". All is now in place for further expansion of the program, in terms of geography – i.e., the origin of providers (currently only Dutch and British) and participants – and the disciplines covered by the courses.

At the same time, Martens sees room for improvement in the program. "Currently, the points awarded for each course reward attendance, i.e. the participants being present during the course days. Naturally they are professionals, so you expect them to follow the courses conscientiously, but it would be better if there were some form of test on the knowledge they obtained during a course." He also identifies some challenges in the certification process, such as 'recruiting' independent experts/professors to assess whether a course is certifiable. There are also concerns around courses that are adapted to local needs for an in-company training session. "Is the original certification still valid? This could be added to the procedure."

Regarding the courses on offer, Martens notes that there is currently a "supplier's push": course developers apply for certification in order to gain some sort of professional recognition. "Ideally, we would have 'demand pull', where the precision engineering community defines the need for certified courses, existing as well as newly developed. This is not yet the case. There isn't a plan, for example, on the top three courses that should be developed. At the moment, what we do is 'gating': checking at the gate which courses can be admitted to the ECP² scheme."

Even further beyond the horizon is the definition of a comprehensive post-graduate precision engineering curriculum. At the moment, the complete offer is so extensive that the gold level, and hence the status of ECP² Certified Precision Engineer, can already be obtained with a subset. "Should there be requirements regarding participants taking courses across a variety of disciplines to qualify for this gold level? This is still an open issue."

Notwithstanding the already wide range of courses, Martens argues for an extension of the offer. “For example, manufacturability is already covered to some extent, but it should be expanded. In the same manner, serviceability should be a topic in the course offering. A precision engineering design cannot be realised in a commercially viable manner if manufacturability and serviceability have not been accounted for.”

Even in the technical engineering domain Martens sees omissions: for example, software is barely represented. “There are still high-tech companies where the impact of software on the design is neglected. System architects should have some background in software, so software engineering and architecting should be part of the curriculum.”

The same applies to soft skills, such as personal effectiveness and communication. “Engineers can come up with a brilliant design, but if they don’t have the skills to engage all stakeholders, they won’t succeed in getting their design approved. However, I haven’t been able yet to get much support for this idea.”

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MAKING YOUR TECHNICAL DESIGN AN INTEGRAL SUCCESS

AUTHORS' NOTE

Twan Schout works as a mechanical engineer at ASML. Arnold Schout is the owner of Schout DfM, a consultancy in the field of design and manufacturability, based in Waalre, the Netherlands.

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The potential success of a precision design is determined by three factors: **functionality, time-to-market and cost.** During the design phase, however, the **manufacturability** aspects of time and cost are often overlooked, especially when achieving the desired functionality is already challenging. This may lead to a **delay in market introduction** and a **higher cost price than desired.** Therefore, **R&D management should make manufacturability part of every design project** and request that **manufacturability assessments** are performed right from the start of a project.

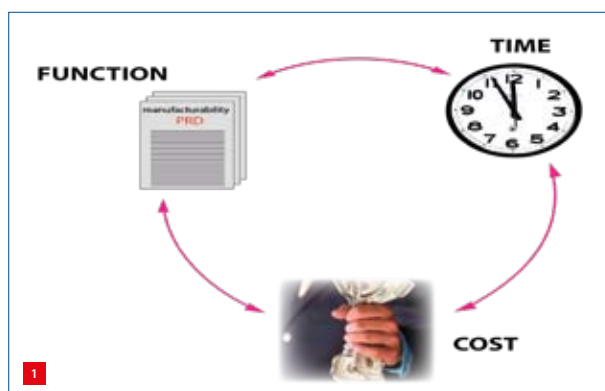
TWAN SCHOUT AND ARNOLD SCHOUT

A successful product has to fulfil a market demand. This implies a design that functions well and can be manufactured at a competitive cost price and subsequently introduced to the market in the right quantities at the right time. Therefore, the comprehensive evaluation of any design addresses functionality as well as manufacturability, i.e. cost and time (see Figure 1).

The development of a successful precision design is an intensive process, composed of tackling challenges by exploring alternative solutions, discussing and aligning within the project team, and deciding which concepts are the most promising and are therefore selected for further elaboration. From high-level concept to final details, multiple design alternatives are conceived. Because it is impossible to elaborate all alternatives, most options will be rejected or put 'on hold' over the course of a project.

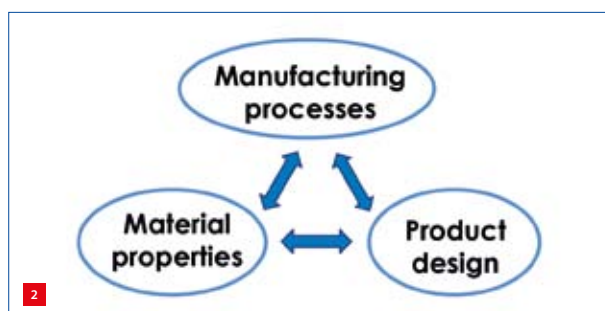
Every design decision will have its impact on subsequent manufacturing and market introduction. When the design has been finished or – even worse – when the chosen design path has led to a dead end, it is often hard to trace back the how-and-why of every design choice. The manufacturability aspects of the design are often overlooked during the design phase, especially when meeting the desired functionality requirements is already challenging. This may result in inadequate manufacturability, often leading to a delay in market introduction and a higher cost price than desired.

It is paramount that all design decisions are made with a



1 The comprehensive evaluation of any design addresses functionality as well as the manufacturability aspects of cost and time. (PRD = product requirements document)

2 Every choice regarding (product) design or material (properties) limits the options for the manufacturing process, and vice versa.



comprehensive overview of their impact on functionality and manufacturability. Therefore, project teams should motivate, underpin and archive their decisions. In order to make the right choices at every step in the development process, the product design details, as well as materials and manufacturing processes, have to be taken into account, since every choice regarding (product) design or material (properties) limits the options for the manufacturing process, and vice versa (see Figure 2).

A true story

A designer (D) consults his colleague, the cost engineer (CE).

D: "Is our design for this subsystem sufficiently feasible?"

CE: "I would advise you to seriously consider improving the manufacturability by avoiding the need of polishing the bottom of a chamber."

D: "Such a redesign study will take us a few months. We don't have that time anymore; we have to continue. But in two weeks we'll visit a potential supplier in Berlin and ask if they can manufacture these products."

Three weeks later.

D to CE: "The supplier is very interested and says he can manufacture it. Nice, isn't it?"

CE: "Yes, that's nice. And when does that supplier think he can come up with protos?"

D: "Oh, we didn't really ask that."

CE: "You should count on at least a year before that supplier can manufacture this difficult product."

D: "That can't be true! We need protos in six months."

CE: "OK. And what will the products cost at 50 pieces a year?"

D: "We didn't discuss that."

CE: "My estimate is that the products will cost about €100k each."

D: "Oh, no! That's double our budget."

D: "Now we have a manufacturability issue!"

Design for Manufacturing

Schout DfM promotes design decision making in a conscious and structured way. The fundamentals behind Schout's Design for Manufacturing (DfM) method will not come as a surprise to many designers. Most of them will already be familiar with them and probably even apply them in their work. However, the breakthrough with DfM is that it provides a structure that makes it possible to discuss and judge the manufacturing aspects at the right time in a language understandable to the entire project team – from project lead to designer and from purchaser to supplier. This helps to ensure that the decision made is endorsed by all stakeholders.

From the starting point of the work by pioneers Boothroyd, Dewhurst and Knight, first published in 1990 [1], the DfM method has been extended. Whereas they focused on cost-price reductions of existing designs based on detailed manufacturing estimations including assembly studies, the DfM method entails a total approach to product development. It also includes the manufacturing aspects in the design phase, which enables a smooth transition from design to production. In essence, it is a 'first-time right' approach. Therefore, it is best to start using the DfM method as early as possible, preferably in the concept phase,

and sustain its application until the product and production processes have been released.

If manufacturability is only assessed at a later stage, it is often difficult to implement any changes that are suggested, because they require reconsidering design choices that have been made and redoing part of the design work, which is often undesired. Changes that would have eased the production and thereby reduced the cost and lead time are therefore often skipped.

Suppliers involved at a later stage will notice their customer's reluctance to change and are therefore discouraged from giving full feedback, only being willing to address the inevitable big issues. On the other hand, it is impossible to involve all possible suppliers at an early stage, when for instance material and/or decisive product details are still under consideration.

Manufacturability criteria

A design decision (see Figure 3) is based on three aspects at the main level. The first aspect concerns the functionality: "Will the designed product function according to the requirements?" Needless to say, to be able to clearly assess functionality, it is critical to have a complete and clear definition of the set of requirements.

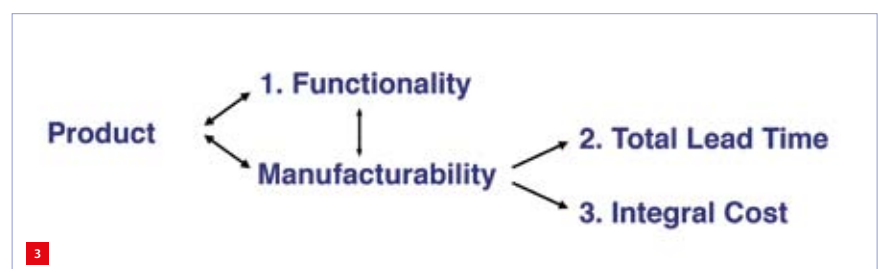
The design alternatives that are expected to meet the functional requirements can be evaluated regarding their manufacturability. Naturally, there is no point in looking into the manufacturability aspects of an alternative that will not meet the functional specs.

Manufacturability can be divided in two aspects:

- Total lead time
The time it will take from 'now' until the moment production can be up to speed.
- Integral cost
All the costs for further development of product and process, including all costs to manufacture products during a defined time of series production (often two years).

Note: Only the future and what can still be influenced is of interest. History is not taken into account here.

3 A design review and subsequent decisions encompass functionality and manufacturability.



4 Evaluating design alternatives in the DfM matrix; here functionality is designated by "Requirements". Alternative 1 scores best on functionality, but alternative 2 shows better manufacturability potential. So, further study is required. Alternative 3 does not meet functional requirements, so evaluation of manufacturability has been skipped.

It is important to realise that these three aspects together form a complete and non-overlapping set. This prevents confusion and discussion about the assessment criteria and simplifies evaluation of alternative designs.

From experience, we know that being on time in the market, represented by the total lead time, is of greater importance than the integral cost. This is due to the fact that being (too) late to the market means that revenue is generated later than expected, and there is the risk that – if the competition is faster – there may be no market left at all. Selecting alternatives with a lead time sufficiently shorter than required also provides some flexibility with respect to changing markets. Giving total lead time priority over integral cost in a design decision will lead to less stress, less extra cost and earnings that come at the planned moment.

In the assessment of the total lead time, the time it takes to get the production process up to speed is often overlooked. Real production does not start when the product is released: first, the production process, including all checks, needs to be in place. Fine-tuning the production process can only start when the first (proto) product is available. A salient observation is that time-to-production is regularly estimated to be nine months – and in some cases, the estimate remains 'nine months' for several years ...

Integral cost is a fairer criterion than product cost only, because integral cost takes return on investment (ROI) into account. For example, in the case of small series, the development cost can constitute the major part of the total cost. Then it is often profitable to accept higher production cost per product instead of spending development time and effort to reduce the product cost price. A suggested rule of thumb is to take all product cost over a period of two years into account, and then to optimise ROI. It is up to R&D management to set an appropriate period for ROI calculation.

DfM matrix

Using a DfM Matrix (Figure 4) is the best method to gather and summarise all the information needed to evaluate various alternatives regarding the three criteria. It gives a clear overview of the multiple alternatives and helps decision making by evaluating the three aspects. The concepts that are expected to provide satisfactory functionality can be evaluated regarding total lead time and integral cost. While this may be done by a quick approximation, a design decision will be more undisputed when the score is based on a more solid estimation. A designer should take charge here, but they are not expected to be able to make all the estimations themselves with enough accuracy; for all aspects, a specialist can be consulted.

Evaluation Criteria	Design alternatives			
	Alternative 1	Alternative 2	Alternative 3	
Functional specification	++	+	–	
Total Lead time	–	++	×	
Integral Cost	+	+	×	

The experience present in the company is usually a good basis on which to start implementing DfM. The assessment can be supported by rules of thumb, formulae, checklists, databases, expert knowledge and supplier information (see the box for a practical example on wire-eroding vacuum parts).

As an additional benefit, using the DfM matrix helps to document the design decisions and considerations in a clear and simple way. It shows which alternatives have been considered, what their strong and weak points are, and what the driver for the final decision was. Documentation of the decisions is vital in preventing unnecessary reconsideration of decisions or making the same mistakes during a redesign. The matrix also helps during the design phase when improvements or changes are needed. It offers the possibility of returning to particular decision moments and considering whether a decision is still valid or if an alternative is needed.

As with all design methods, feedback loops are inevitable. Stubbornly continuing in a direction is often very counterproductive.

Team roles

As stated earlier, evaluating the manufacturability aspects of the design is a responsibility shared by the entire team.

Example: Wire-eroding vacuum parts

Consider a frame containing a few details that have to be wire-eroded. Accuracy and surface roughness are known to be the cost drivers of wire erosion. A new design of the frame will be used in a high-vacuum application. What are – according to a supplier – the manufacturability consequences?

Normally brass wire is used, but this poses a contamination problem because of several alloy constituents emanating from brass wire. The alternative is using copper wire. Due to the lower tension copper wire can be subjected to, additional process development will be required, taking several weeks. Also, the eroding speed has to be halved to achieve the same accuracy, which will double the cost of wire-eroding.

Logically, the project lead will focus more on the timing, whereas the purchaser and cost engineer will provide input on the cost. The designer plays the main role, however, in developing the alternatives and gathering the information on which the decisions are based. So, it is important that the designer takes ownership of product development, realising that their design is the basis for the success of the product. In other words, many of the future (manufacturing) problems evolve from the design.

It is the responsibility of R&D management to promote the adoption of a DfM method. Although in principle the method is straightforward, implementation may not be easy, as it raises some new questions on manufacturability compared to standard engineering practice within a company. It is recommended to start in a pragmatic way, engaging all disciplines involved, and monitor progress.

Conclusion

The DfM method discussed here presents a comprehensive and structured design approach; see the box for recommendations about its adoption. It includes summarising requirements, comparing alternatives, making estimations, and evaluating functionality, total lead time and integral cost. Thus, it is an assessment method that leads to well-considered and accepted design decisions. As a consequence, dealing with manufacturability aspects benefits from a 'first-time right' design approach, saving a lot of time, effort and cost that would otherwise be spent in improving product manufacturability afterwards. ■

REFERENCE

[1] G. Boothroyd, P. Dewhurst and W.A. Knight, *Product Design for Manufacture and Assembly*, 1990. For the second edition, see →



Recommendations

1. Adopt a DfM method.
2. Increase the knowledge of manufacturing processes.
3. Stop limiting the design focus to technical challenges, which is what most engineers prefer to do, and focus on the manufacturability aspects as well.
4. Be aware that selecting a supplier drives the design in a certain direction, because of the supplier's limited scope in manufacturing processes.
5. Be aware of the necessity of developing manufacturing processes for every part and assembly. So, involve the supplier in an early stage when there is still design freedom.
6. Provide more education and training in design methods to students and engineers alike, involving the total design process, from invention to manufacturing process design.
7. Schedule time to incorporate manufacturability in the design stage. "Don't be the lumberjack who doesn't take time to sharpen his axe, because there are too many trees to cut down."

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EDITORIAL NOTE

This article was contributed by the TU/e HTSC.

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Tim Verdonshot is an Eindhoven University of Technology (TU/e) graduate, first as a Bachelor of Electrical Engineering and then as a Master in Systems & Control (an interdepartmental Master's programme of the departments of Electrical and Mechanical Engineering), who was faced, like many fellow graduates, with a choice about the next step in his career. The Ph.D. route offered one option but more attractive was the PDEng education, Professional Doctorate in Engineering, at the High Tech Systems Center (TU/e HTSC) on the TU/e campus in Eindhoven, in Mechatronic System Design, a two-year programme with an industry link and the opportunity to work in teams.

Verdonshot is currently engaged in the second year of this two-year programme and focusing on a project aimed at developing the machine control system architecture for the so-called 'Lepus Next Gen' printing equipment (Figure 1) of the AMSYSTEMS Center, a joint innovation centre of TNO and TU/e HTSC, such that actuators, sensors and feedback control can be incorporated into the machine control. This Mechatronic Systems Design project called for a mechanical or electronical engineering education, specialised in systems and control, with an affinity for control systems design and (firmware/software) implementation. Step in Tim Verdonshot.

More than just an engineer

"What appealed to me was the opportunity to be practical. I am more motivated by application than by academic research. During my first year I followed a dedicated curriculum of courses, interactive workshops and group and practical assignments, often in close cooperation with industrial partners, the core of which is formed by system architecture and design. But apart from the more technological content, we also had to acquire professional skills such as project management, communications and how to handle conflicts. These are things that can give you that bit extra that companies are looking for these days, and especially in a



- 1 The Lepus Next Gen printing equipment. (Photos: Bart van Overbeeke)
- (a) Tim Verdonshot in front of the machine.
- (b) Close-up of a dispensing unit for deposition of conductive tracks for 3D-printed electronics applications.

design project, which covers the second year of the programme, where I am right now, we get the chance to show what we can contribute."

Control loops

Gregor van Baars, senior system engineer and project manager at AMSYSTEMS Center, where Verdonschot is doing his project, explains the nature of the problem. "At TNO we have developed prototype AM (additive manufacturing) equipment based on vat photo-polymerisation (stereolithography). The machine platform, called Lepus Next Gen, contains a unique lighting module that enables scaling up to large-area additive manufacturing for pure (curing) polymers as well as photopolymers mixed with ceramics particles."

When the AMSYSTEMS Center was established, TNO brought in the Lepus Next Gen into the cooperation and common infrastructure. "Most of the current AM equipment, however, is operated in open loop, which means the machine parameters are set to fixed values without corrections during the manufacturing of the part. Since AM offers new opportunities for the design and manufacturing of high-tech ceramic machine parts, at reduced cost and shorter lead times than conventional ceramics manufacturing technologies, we want to develop the tightly coupled AM process, materials and equipment in an integrated fashion."

So within AMSYSTEMS Center there is an ongoing research programme on large-scale ceramics AM. One of the routes to improvement is to introduce control loops, Van Baars continues. "This requires the integration of actuation, sensing and feedback control principles into the Lepus Next Gen platform. So we took the option to strengthen our AM ceramics research with three PDEng final year projects to be carried out as a team of PDEng engineers at the facilities of AMSYSTEMS Center. Tim Verdonschot is working on the control loop."

Valuable feedback

Tim Verdonschot: "What we want to do is to add sensors to measure the process so that when the layers are added, the resin hardens in the right way and the whole process is controlled and optimised. My role is to ensure that the hardware and machine software that is used can be adapted such that other sensors and actuators can be added, and to modify the software so that everything works in harmony and that the sensor readings are clear and give us the information to be able to make the necessary adjustments."

In fact, Van Baars adds, "what Tim is doing in this project plays quite an important role in the development of these machines since what we have with the first generation is not the ultimate. Mechatronics and system engineering is becoming increasingly integral to 3D printing equipment. After all, it involves processes and materials that demand a different kind of control issue than, for instance, the precision motion systems in ASML's lithography wafer scanners. So what we try to do is to exploit available system engineering and mechatronics expertise for new applications like 3D printing. And what we have tried to do with the three PDEng projects is to look at the three different aspects: measurement, layer deposition (recoating) and control. And this last aspect is the focus of Tim's work."

Perfect fit

The fit with the first year of Verdonschot's programme where systems engineering was a key component makes the project even more rewarding since he is able to really put to the test what he has learned. "My study and the project slotted together perfectly. And another thing that is really pleasing is the collaboration and collegiality at AMSYSTEMS Center. I feel I'm always able to knock on the door and ask questions, and everyone is willing to share their knowledge and experience with me. While it is great to be using and developing my own knowledge and skills, the sense of being part of the greater whole is an added bonus. You certainly get a feel for what it is to work in the 'real world' as it were."

Van Baars comments: "That's quite essential, too, in this relatively new world of 3D printing. Both sides benefit from each other. Through asking questions and getting answers, needs can be met. So this access to expertise gets Tim further along the path of his assignment."

To be continued ...

Verdonschot's assignment is for a year and while he is making real progress, the likelihood of him completing the goals of the project is hampered by the time factor. "Along the way we have encountered several problems that had not been anticipated so it is not realistic to think that we will be able to finish everything in the time we have. But we have reached the point where the software and hardware are such that we can add the sensors and actuators, and implement closed-loop process control in the system. So, in that respect, we are not running behind what we set out to do. It is a fairly new and unexplored area, so you often have to take one step back to go two steps forward."

This progress benefits not only Tim Verdonschot but also AMSYSTEMS Center. "It helps us move forward", says Gregor van Baars. "We will have gone from nothing to something, so that is a very tangible yardstick of achievement. The PDEng trainees in this project will have brought us to the point that we can now measure and control. To get from there towards the ultimate system performance, the work will continue, and PDEng trainees will certainly be part of that continuation." ■

The two-year, full-time PDEng programme Mechatronic Systems Design

In the first year, the PDEng student learns new technologies and broadens and deepens his/her knowledge of mechatronics in a broad sense, spending about half of the time following courses and workshops, and the other half working in multidisciplinary teams on projects (real problems) from industry that are assigned by industrial partners, including well-known international companies such as ASML, TNO, ESA, VDL, and NXP, but also promising high tech start-up companies in the Brainport region. The second year is spent in industry working on an individual, challenging and innovative technological design project – a real problem that needs a solution.

WWW.TUE.NL/MSD

TALENT DEVELOPMENT IN A HIGH-TECH ENVIRONMENT

The role of the technical engineer is changing due to the increasing use of data in decision making, the expanding focus on customers and design, and changes in software development methodologies. On the other hand, high tech companies are struggling to find and keep high-tech talent for their development organisations. This is where talent development as one of the key missions of any organisation comes in. For Holland Innovative it's not about strategy, it's about culture. People – and their ability to lead diverse, flexible and versatile teams – are of the utmost importance to ongoing success.

EDITORIAL NOTE

This article was contributed by Holland Innovative, a specialist consultancy in project management, product and process development and reliability engineering, based in Eindhoven and Enschede (the Netherlands) and Straelen (Germany).

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Although business is fast-paced all over the globe, working at the High Tech Campus Eindhoven, the heart of the Brainport region amid the ever-shifting tech industry, we at Holland Innovative often find ourselves on the forefront of emergent business needs. Today, more and more of our clients and colleagues are talking to us about the need to build comprehensive programmes for talent management. More than ever, companies are realising that their people are of the utmost importance to success. Talent management is changing, and that change is driven by a number of trends.

ATD research [1] named these top trends influencing the next five years of global talent development:

1. The need for an innovative workforce.
2. More flexible organisations to adapt to our rapidly changing world.
3. Changes in skills needed for success in the workplace of tomorrow.
4. Employees demanding more of employers.

Holland Innovative recognises the urge for top technical talent at customers and feels the need for the same talented



¹ For Holland Innovative, talent development is about culture. (Photo: Gijs van Ouwerkerk/Holland Innovative)

people to help grow its own business. In this changing landscape we see a number of components that build a comprehensive talent development programme:

1. Talent management vision, values and goals

Drawing up a clear definition that supports business objectives. This serves as the framework to build and prioritise all other programmes. It means looking beyond filling positions – it's considering how talent ties in to the goals of an organisation and determining what roles are needed to make those goals a reality.

2. Talent development framework

Building an end-to-end framework that serves as the roadmap or programme for how to attract, retain and build talent. A diverse talent pool opens up networking capabilities, is proven to drive innovation, and helps attract top talent. In our own organisation and at customers we see very diverse teams; in age (from 28 to 68!) and gender, as well as in cultural and technical background.

3. Talent gap assessment

Serving as the baseline of near-term competencies and actions that need to occur to shore up immediate gaps and guide long-term talent investments: This is where consultants and flexible professionals are a useful investment. Bringing in individuals or teams with specialist technical expertise can help drive projects to success while the organisation is in the process of developing long-term staff.

4. Talent succession plan model

Defining the roles, responsibilities and demonstrated capabilities needed for the future. At Holland Innovative we use the 'good old' master-apprentice model where masters in their specific area of expertise train and guide their colleagues and take care of talent succession.

5. Employee engagement programme

Measuring perceptions of the workforce and providing data to leadership on the true pulse of the culture and the workforce: Once a 'top' team has been recruited, it's critical to monitor key measures of employee satisfaction such as making sure team members have access to the resources they need, aren't moving toward burn-out, and feel part of the workplace culture. Aim to build in processes that help ensure employee satisfaction and retention, and help maximise the return on the biggest investment: people. ■

REFERENCE

- [1] "The State of the Industry" report on training and development trends, 2017, ATD Research, www.td.org

Leadership in product and process development

"At Holland Innovative, we have long recognised that people are the heart of any organisation and the true drivers of innovation and ongoing success. We have years of experience helping organisations and our on-demand workforce and consulting services help to grow teams and drive success as we roll out and build on our critical programmes: project management, product and process development, and reliability engineering.

For us it's all about both heart and mind. In order to attract and retain top technical talent we listen to each other: Where are your ambitions? Where can we support your passions in life? What does your heart tell you? Writing a book, supporting student teams, peer coaching, becoming a teacher, developing your own idea into a product ... By providing support to our employees we help them in finding the balance between work, ambition, fun, personal life, passion and all that's important in life."

Holland Innovative provides inspiration with leadership and training in product and process development, project management and reliability engineering. Challenging projects ensure clients and experts are sharply focused. The customer base includes leading multinationals, SMEs and start-ups. They all have a strong desire to do things differently – in a better way. All projects arise from a customer requirement and a clear business case. The proven methods are strongly analytical, leading to a robust product with a predictable lifespan which can be brought to the market more quickly.

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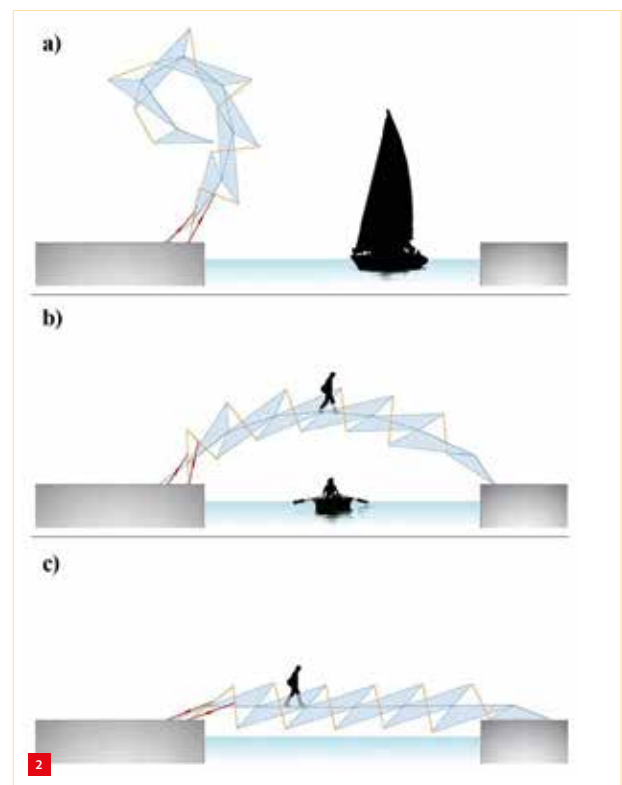
“THE MOST CREATIVE CONFERENCE IN MECHANISM SCIENCE”

A reconfigurable mechanism can be defined as a mechanism with changing mobility due to its specific mechanical design, for example changing from a configuration with one degree of freedom to a configuration with two degrees of freedom motion. Due to the practical and theoretical challenges of developing a reconfigurable mechanism and also because of the high variety of design possibilities, this topic pushes the designer to employ all of his or her creativity.

VOLKERT VAN DER WIJK AND JUST HERDER

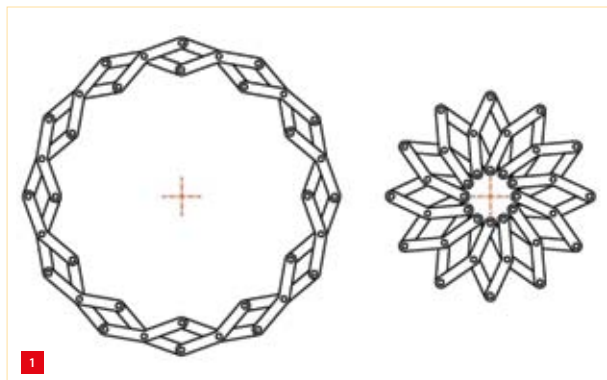
Reconfigurable Mechanisms & Robots was the topic of the international IEEE/IFToMM conference ReMAR held at Delft University of Technology from 20 to 22 June 2018. It was the 4th edition of the conference which the organisers subtitled as “the most creative conference in mechanism science”.

‘Reconfigurable’ can have a variety of meanings. A common explanation of a reconfigurable mechanism is a mechanism with changing mobility due to their specific mechanical design, for example changing from a configuration of one degree of freedom motion to a configuration of two degrees of freedom motion. This can be exploited by creating mechanisms with multiple operation modes that bridge the gap between machines, which are fast but can typically only perform one motion, and robots, which are not as fast but are highly flexible in that they can perform almost any motion within their reach. This is relevant at many length scales and applications ranging from cranes, kinetic art and robotics, to medical instruments and micro-devices.



Scissor linkages

The conference showed the latest advances in this field, as well as related peculiar mechanisms. Keynote speaker Gökhan Kiper (IYTE Izmir, Turkey) gave an extended overview and classification of the design of scissor linkages. These linkages are the basis of a large range of deployable structures, i.e. structures that can be both folded compactly and deployed to span a large space. The Hoberman Sphere (Figure 1) is a well-known deployable toy consisting of such scissor linkages [1].



1 A Hoberman Sphere [1].

2 A deployable scissor-linkage bridge [2].

AUTHORS' NOTE

The organisers of the ReMAR 2018 conference, Volkert van der Wijk (assistant professor) and Just Herder (professor), are associated with the Mechatronic System Design (MSD) research group of the Department of Precision and Microsystems Engineering at Delft University of Technology, the Netherlands.

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In his lecture, Kiper explained how scissor linkages can be generalised and how they can be better treated as scissor units, focusing not on the individual links but on the closed loops that two connecting scissor linkages form and use these loops as building blocks in the design. Concepts and prototypes of practical applications were illustrated, including deployable roof structures for portable emergency shelters and a bridge across the water which can deploy to open for boats and to close for pedestrians (Figure 2).

Architected materials

Jonathan Hopkins (University of California, Los Angeles, USA) gave a keynote lecture on architected materials, also referred to as mechanical metamaterials. These complex monolithic movable structures achieve properties that derive primarily from their microstructure instead of their material composition.

The microstructures of such materials typically consist of tiny compliant and often reconfigurable mechanisms that collectively work together within large lattices to produce extreme combinations of bulk super properties, which are not achievable by natural or synthetic homogenous materials.

Examples of such properties include engineered energy absorption and stress-wave propagation behaviours, extreme shape-reconfigurability, actively tuneable mechanical properties that can be programmed and uploaded wirelessly, and computational sensing achieved by mechanical-logic-inspired lattices.

Hopkins' lecture gave an overview of the design and fabrication tools that his Flexible Research Group has generated in the context of practical architected-material applications. These design tools leverage the simplified mathematics of the Freedom and Constraint Topologies (FACT) [2] synthesis approach to rapidly search the full design space of both periodic and aperiodic architected topologies to achieve desired combinations of properties. The group's fabrication tools utilise custom-developed components (e.g. a flexure-based micro-mirror array) to generate multiple optical traps that are independently controlled to assemble large numbers of different material micro-particles simultaneously for rapidly constructing desired microstructures.

The aim is to bridge the gap between the knowledge currently being generated in the field and the practical implementation of that knowledge for commercial applications. The two major advances required to bridge that gap include: dramatically improved design tools handling the infinite design space of microstructural solutions and new additive technologies that can fabricate practical volumes ($> 1 \text{ m}^3$) of such lattices that often consist of multi-material true-3D submicron-sized features.

Kinetic art

To stimulate a creative atmosphere, the conference was opened with a keynote lecture by Delft-based kinetic artist Theo Jansen. He explained and demonstrated how reconfigurability is at the core of the designs of his 'strandbeesten' (beach animals): large walking creatures made of yellow electricity tubing, which use wind as energy source to live on beaches.

For instance, the self-propelling beach animal Animaris Percipiere uses a 'stomach' of recycled plastic bottles that contain air to store energy. They are pumped to a high pressure by the wind and the animal's wings. This air is used by artificial muscles to drive and control the animal. The muscles act as a kind of piston which can open taps to activate other muscles that open other taps, and so on. This creates control centres which can be compared to brains.

After explaining how he obtained the exact design of his world famous strandbeest leg in the late 1980s with the aid of genetic algorithms, Jansen demonstrated the muscles and the brain communication by means of the mechanical nerves (Figure 3). With these devices the beach animals can, for instance, communicate, sense, react to water by walking away from it, and attach themselves securely to the sand when the wind becomes too strong.

WWW.STRANDBEEST.COM



3 Theo Jansen (left), assisted by conference co-organiser Just Herder, demonstrating the strandbeest's artificial muscles and brain communication by means of the mechanical nerves.

Soft robots

The keynote lecture of Metin Sitti (Max-Planck Institute for Intelligent Systems, Stuttgart, Germany) was all about reconfigurable mechatronics applied for micro-biorobotics. He presented their recent activities on design, manufacturing, and control of new shape-programmable untethered soft robots at the milli/microscale. These are based on soft functional active materials that can enable physical intelligence for small-scale (from a few millimeters down to a few micrometers overall size) devices and robots by providing them with unique capabilities, such as shape changing and programming, physical adaptation, and multi-functional and drastically diverse dynamics.

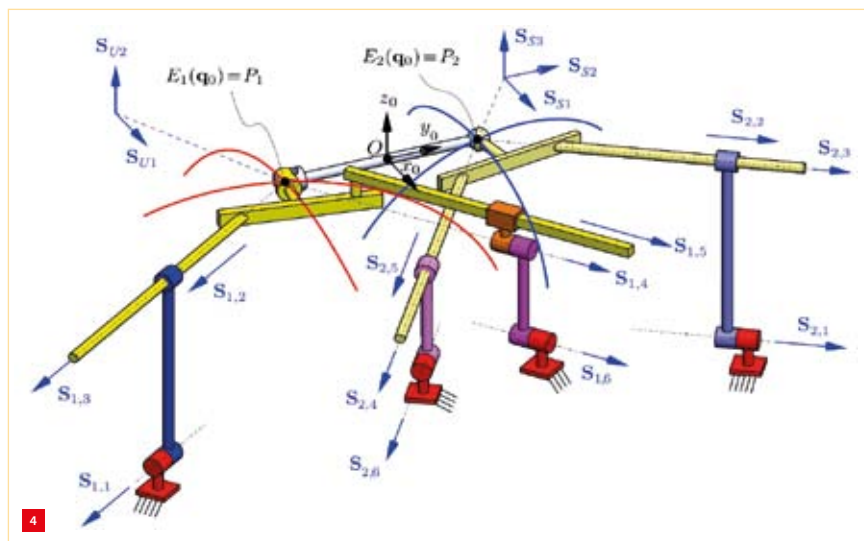
First, a computational design and fabrication method to create 2D shape-programmable magnetic soft elastomers was shown that can generate the desired large number of shapes using a programmed non-homogeneous magnetisation profile and uniform magnetic field control

input. Using such methodology, a grand challenge in small-scale mobile robotics was addressed: how to navigate mobile robots in complex environments with multiple terrains (e.g. on solid surfaces, inside fluids, at the fluid-air interfaces) using multiple locomotion modalities like animals in nature? An example was shown doing undulatory swimming, jellyfish-like swimming, water meniscus climbing, jumping, ground walking, rolling, and crawling to navigate in a complex environment, such as inside the human body. One of the interesting potential applications shown was the ultrasound-guided navigation of such a soft robot inside ex-vivo chicken tissue towards their medical applications to deliver drugs and genes locally, and heat the local tissues for hyperthermia and cauterisation.

Auxetic behaviour

During the conference four awards were presented. The best theoretical paper award was for the research by Ciprian Borcea and Ileana Streinu on a longstanding open problem in auxetics. Where most materials become laterally thinner when stretched, auxetic behaviour is the opposite with lateral widening upon stretching, a property often studied in meta-materials. A theoretical understanding of the role of geometry in auxetic behaviour has been a challenge for a long time.

They showed that for structures modelled as periodic bar-and-joint frameworks, including atom-and-bond frameworks in crystalline materials, there is a complete geometric solution, opening endless possibilities for new auxetic designs. They constructed a large family of three-dimensional auxetic periodic mechanisms and discussed the ideas involved in their design.



Spatial linkage

The award for the best student paper was given for the research by Pablo López-Custodio, et al. who presented a completely new reconfigurable spatial linkage (see Figure 4) with cusp singularities and multiple branches of motion, referring to it as the double-Koenigs mechanism. The white bar with point O is the reconfigurable end effector of the manipulator. This bar is connected with the couplers of two Koenigs joints, which are in fact closed-loop linkages.

The Koenigs joint is known as a constant-velocity shaft coupling that allows transmission of rotation between two non-collinear axes at a rate of 1:1, but here the Koenigs joint was generalised to have spatial motion with links of unequal lengths. The local mobility and singularity

4 The double-Koenigs mechanism, a completely new reconfigurable spatial linkage [4].

Conference wrap-up

Around 105 participants from 25 countries in five continents participated in the ReMAR 2018 conference. Sixty papers were accepted after peer review and will be published in IEEE Xplore. All the authors presented their work in a three-minute podium pitch and a 90-minute interactive session, which was an excellent combination for showing and discussing the research with prototype models, demonstrators, videos and posters in a relaxed setting.

The conference site was within the TU Delft Mechanical, Maritime and Materials Engineering faculty building, which allowed all participants to feel the vibe of the first-year mechanical engineering students who at exactly the same time were testing and presenting their machines for the annual mechanical engineering design contest. The social activities, namely the welcome reception at the historic city hall and the canal boat trip to the conference dinner in the Old Church, were also well received.

The next (5th) conference on Reconfigurable Robots & Mechanisms will be in Toronto, Canada, in 2021.



WWW.REMAR2018.ORG

analysis of this complex mechanism showed to be a challenging problem for which common methods proved inadequate.

Origami

The best application award was given to Todd G. Nelson, et al. for their research on the implementation of rolling contacts for the so-called synchronised-offset-rolling-contact element (SORCE) joints. These joints were developed for thickness accommodation in origami-inspired mechanisms, combining selected strengths of several thickness-accommodation techniques, but with the trade-off of manufacturing complexity of rolling joints. Principles to facilitate the construction of rolling joints suitable for applications like the SORCE technique were presented. These include leveraging fold-angle multipliers of origami vertices, variations of flexure assembly, sunken flexures, and form-closed rolling joints. Prototypes of origami mechanisms using the SORCE technique were constructed and shown to demonstrate these principles. The technique is also well suited for use in other areas where rolling joints are beneficial due to their unique qualities of a moving axis and low friction.

Additional degrees of freedom

The most creative presentation award was given to Abhilash

Nayak, et al. for presenting their work on a dual reconfigurable 4-rRUU parallel manipulator. This is a manipulator where the moving platform is connected to the base by four kinematic chains or 'limbs' with revolute and universal joints. They showed how they used a double Hooke's joint linkage to reconfigure the base revolute joints of a 4-RUU parallel manipulator whose platform motion then depends on the angle between the driving and the driven shafts of the double Hooke's joint linkage in each limb. With this construction the rotational input motions of the shafts of the fixed motors are changed into another direction such that each limb obtains a variable orientation of the base R-joint. Due to the additional degrees of freedom the resulting 4-rRUU parallel manipulator can move into a variety of operational modes. This was wonderfully demonstrated by a prototype, videos, pictures, and simulations. ■

REFERENCES

- [1] C. Hoberman, "Mechanical Invention Through Computation - Mechanism Basics" MIT Class 6.S080 Lecture Notes, 2013, courses.csail.mit.edu/6.S080/lectures/02_all.pdf
- [2] Ş. Gür, M. Yar and K. Korkma, "Çok fonksiyonlu form değiştirebilir köprü tasarımı için iki serbestlikli strüktürel mekanizma önerisi", *Journal of the Faculty of Engineering and Architecture of Gazi University* 32:4, 1379-1391, 2017.
- [3] J.B. Hopkins, "On the use of Freedom and Constraint Topologies - Precision flexure bearing design", *Mikroniek* 52 (5), pp. 34-39, 2012.
- [4] P. López-Custodio, et al., *Proceedings of the 2018 International Conference on Reconfigurable Mechanisms & Robots (ReMAR 2018)*.

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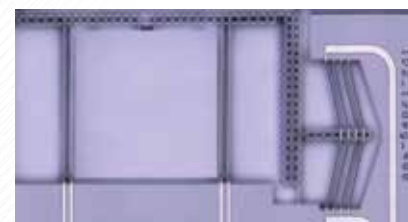
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ON-CHIP ACTUATION FOR WAVEGUIDE ALIGNMENT

Recent decades have seen impressive developments in the field of integrated photonics. Chips with complex photonic functionality can presently be designed and fabricated. Photonic packages consist of one or more PICs, as well as other (micro-optical) components, and a fibre (array) to establish the external optical interface. A core challenge is the assembly and packaging of these complex devices, involving sub- μm alignment of components. To overcome the limitations in multi-chip photonic packaging, a concept is proposed which uses on-chip actuators for the fine-alignment of flexible waveguide structures.



MARCEL TICHEM, TJITTE-JELTE PETERS AND KAI WU

Motivation

Chips with photonic functions, i.e. photonic integrated circuits (PICs), with complex functionality can presently be designed and fabricated at cost levels which are acceptable for a variety of applications [1]. Photonic packages consist of one or more PICs, as well as other (micro-optical) components, and a fibre (array) to establish the external optical interface. A core challenge is the assembly and packaging of these complex devices.

Assembly and packaging in the photonic domain is much less standardised compared to the microelectronic domain, and is a dominant cost factor. Particularly, the precise, sub- μm alignment of components is demanding. The currently dominant industrial approach to assembly is to use micro-positioners in a semi-automatic process for handling of components and joining methods like adhesive joining for locking in the final position.

Here, the aim is to reduce cost as well as assembly time by proposing a new concept, which exploits MEMS technology

for the fine-alignment of flexible optical waveguide structures [2] [3] [4]. The concept has the potential to allow for full automation of the assembly process, thus reducing operator involvement. It is developed for new generations of photonic packages, containing multiple PICs with multiple optical I/O.

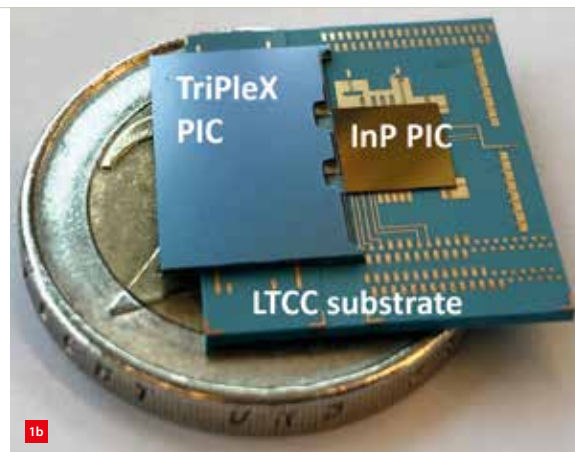
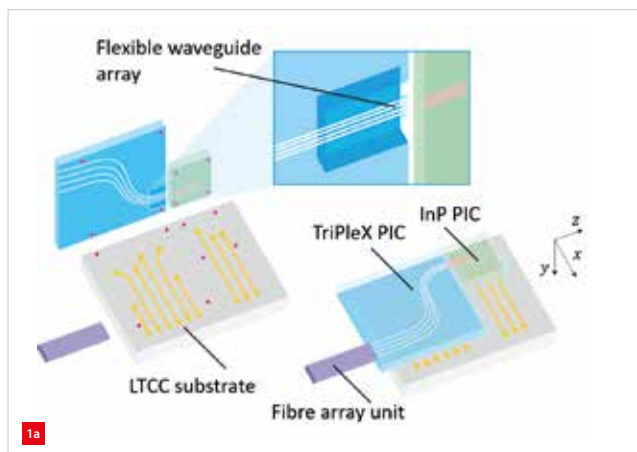
Figure 1 shows a schematic package overview, which combines an InP (indium phosphide) PIC with active optical functions (e.g., lasers and detectors) and a TriPleX-based PIC (Si_3N_4 waveguide cores in SiO_2 cladding material [5]) with passive optical functions. The TriPleX PIC acts as an interposer chip, to interface the InP PIC on one end to an optical fibre array at the other end. Its main functions are spot size conversion and waveguide pitch conversion. To prevent losses when interfacing waveguides, the spot sizes should match. The spot size at the InP interface is $\sim 3\ \mu\text{m}$, whereas on the fibre interface the spot size is $\sim 8\ \mu\text{m}$. One of the advantages of the TriPleX technology is that it allows on-chip spot size conversion.

1 Multi-chip photonic package.
(a) Schematic overview.
(b) Flip-chip bonded InP and TriPleX PIC on a common substrate (LTCC, Low Temperature Co-fired Ceramics).
(Courtesy of PHASTFlex consortium [4])

AUTHORS' NOTE

Associate professor Marcel Tichem and Ph.D. candidates Tjitte-Jelte Peters and Kai Wu are all attached to the Micro and Nano Engineering research group in the Department of Precision and Microsystems Engineering at Delft University of Technology, the Netherlands.

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The next sections introduce the alignment concept, present a typical design, and describe results.

Alignment concept

The assembly process is split into two steps: chip pre-assembly and waveguide fine-alignment. Chip pre-assembly is done by flip-chip placement and bonding of the two PICs on a common carrier. The waveguide positions are well-defined with respect to the active surface of the PIC, hence flip-chip bonding allows obtaining good precision in initial alignment.

When using small solder bumps, the initial precision can be controlled within $\sim 1\text{--}2\text{ }\mu\text{m}$. This is sufficient for the less critical alignment directions (translation in the z -direction, rotation in the x - and y -direction, see Figure 1). The remaining error in the critical directions (translation in x - and y -direction, rotation in z -direction) is subsequently compensated by a fine-alignment step, using flexible waveguide beams and MEMS (microelectromechanical system)-based functions, which are integrated with the TriPleX PIC.

Three main functions are needed on the TriPleX chip for waveguide fine-alignment: (1) flexible waveguide structures, (2) actuators for positioning the waveguide structures, and (3) a locking function to maintain the final position. Here, the focus is on flexible waveguides and positioning; the locking function is topic of further investigation. The functions are realised by post-processing of a TriPleX wafer. The optimal position is found in an active alignment scheme, i.e. by measuring and maximising the coupled power while moving the waveguide beams. To this end, light sources, detectors, and alignment waveguides are added to the InP and TriPleX PIC design. The targeted precision, waveguide-to-waveguide, is 100 nm. Given the precision of the chip pre-assembly process, the required motion range (translation directions) for the waveguide beams is in the order of $4\text{ }\mu\text{m}$.

Design

The MEMS functions are fabricated in the optical stack of the TriPleX material platform, which is a $16\text{ }\mu\text{m}$ -thick silicon dioxide/silicon nitride ($\text{SiO}_2/\text{Si}_3\text{N}_4$) layer on top of a silicon wafer. This is an innovation in itself, as the usual building material for MEMS is silicon. A challenge in the fabrication of SiO_2 -based MEMS is the presence of significant compressive stress, due to the growth of the layer at high temperature ($\sim 1,000\text{ }^\circ\text{C}$). The stress easily leads to fracturing of the structures when released from the wafer. A release process was developed to achieve reliable fabrication of the structures [6]. In this process, when the waveguide and actuator structures are defined by patterning the SiO_2 stack, deep trenches are etched into the Si wafer. Subsequently, the structures are released by etching the Si, starting at the bottom of the Si trench. The initially

significant Si layer underneath the SiO_2 structures prevents their fracturing.

A typical design consists of an array of waveguide beams, see Figure 2. The beams have a typical cross-section of $\sim 16 \times 20\text{ }\mu\text{m}^2$, and a length of up to $\sim 1,000\text{ }\mu\text{m}$. The waveguide beams are connected at their free ends with a cross-bar. In this way, the lithographically defined waveguide pitch is preserved, and the number of actuators required for positioning is limited.

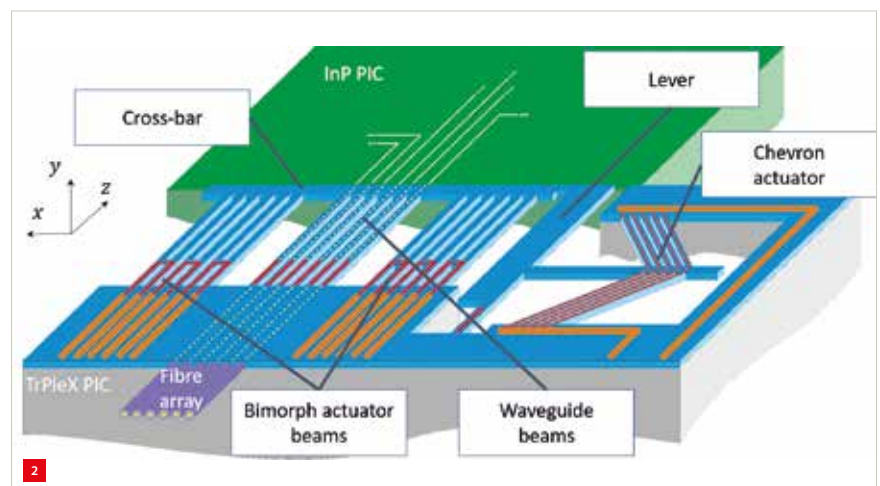
Thermal actuators are used for positioning the waveguide array. They are easily fabricated and deliver significant amounts of work. A set of bimorph actuators beams, with cross-section and length similar to those of the waveguide beams, is placed on either side of the waveguide beam array. When they are simultaneously powered, the array translates in the out-of-plane direction (y). When they are differentially powered, rotation around the light propagation direction (z) is achieved. The bimorph effect is obtained by depositing a layer of boron-doped polycrystalline silicon (poly-Si) on top of the SiO_2 beam; the poly-Si structure is both the heater and the structural layer of the actuator.

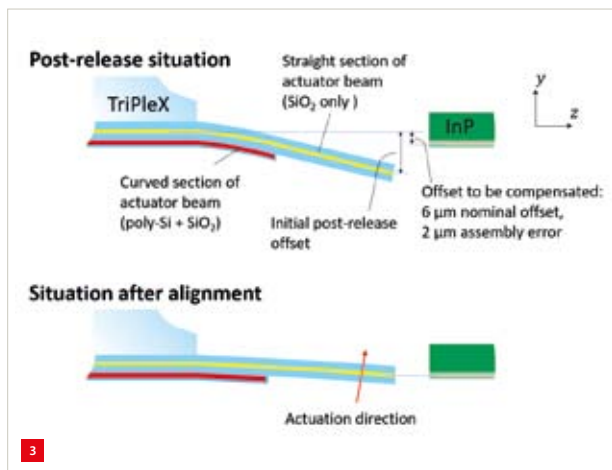
For in-plane translation (x -direction) a chevron actuator is proposed [7]. The actuator beams consist of the same SiO_2 and poly-Si stack. Their expansion upon heating is limited, even for a fairly spacious design. To amplify the chevron motion, a lever mechanism is used.

The combination of SiO_2 and poly-Si ($16\text{ }\mu\text{m}$ and $5\text{ }\mu\text{m}$ thick, respectively) has implications for the post-release deformation and actuator behaviour. Both material layers are grown and deposited at high temperature. The difference in CTE (coefficient of thermal expansion) will result in a post-release curvature. For the chevron actuator, this implies that the actuator will have a complex post-release deformation state, with both in-plane and out-of-plane components. Also, when operated, the actuator will have a parasitic out-of-plane motion, next to the desired in-plane motion.

The bimorph actuator beams will also have a post-release

2 Overview of a typical design. A number of waveguide beams is connected through a cross-bar to sets of bimorph actuators for out-of-plane translation and rotation around the light propagation direction. A chevron actuator, of which the motion is amplified by a lever, generates in-plane motion.



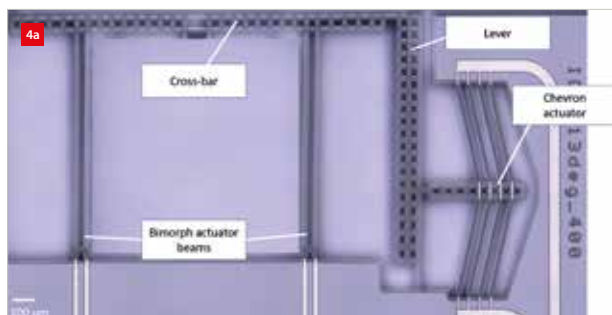


curvature, and this can be quite significant. The bimorph actuator design proposed makes intended use of the post-release deformation [8]. In this design, only a short section of the entire actuator beam is provided with poly-Si. This section will have a post-release curvature, whereas the remaining SiO₂-only section of the beam is almost straight. Hence, the length of the poly-Si section is a parameter that can be used to fine-tune the initial out-of-plane position of the structure.

This is illustrated in Figure 3, which shows a side view of the spatial relation between the chips' waveguide structures. A nominal offset between the waveguide layers of ~6 μm in the vertical direction exists, due to the definition of the material stacks in the optical layers and in the bond-pads. Also, there will be an error in the vertical direction in the flip-chip bonding process ($\pm 1-2$ μm, chip-to-chip). Taking this together, the maximum initial offset between the waveguide end-facets that can be expected is ~8 μm. The length of the poly-Si section is chosen to provide this initial offset. When powering the actuator, the optimal position is achieved.

Results

Along the lines of these principles, a wide range of structures was fabricated. Figure 4 shows two examples: to the left, a simple configuration consisting of four bimorph actuator beams, together with a chevron actuator and lever. To the right, a design consisting of six waveguide beams in the centre, and two adjacent sets of bimorph beams.



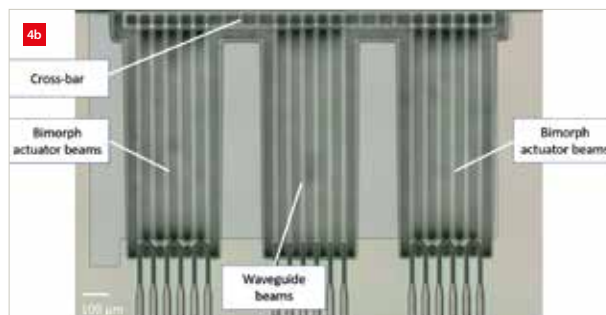
Motion measurement results are shown in Figure 5, for the chip of Figure 4a. The bimorph actuators consist of 40-μm long poly-Si tracks on 900-μm long SiO₂ beams. The chevron actuator is rigidly connected through the lever mechanism to the cross-bar and actuator beams. Since all structures are connected, mechanical cross-talk can be expected. When only one of the bimorph actuators is powered, the entire structure will deform, i.e. also the end-points of the non-powered beams will move.

For instance, see Figure 5a, when operating the left-side bimorph actuators, i.e. the ones furthest away from the lever and chevron structure, the end-points of the corresponding beams move ~3 μm out-of-plane at 55 mW power. At the same time, the end-points of the other beams are also deflected out-of-plane (~1 μm). Operating the other actuator set shows similar behaviour, see Figure 5b. In this case, the out-of-plane motion is smaller at the same power levels, because of the stiffness of the nearby lever and chevron actuator structure.

Figure 5c shows the results of an in-plane motion measurement for the same chip. The central beam of the chevron actuator moves ~600 nm at ~125 mW, while the cross-bar moves ~1.8 μm; this amplification corresponds to the designed ratio of the lever mechanism. The parasitic out-of-plane motion of the chevron actuator is significant, and was measured to be in the order of a few 100 nm.

To demonstrate the actual coupling of light, a chip with a waveguide array and bimorph actuators on either side of the waveguide array was pre-positioned with respect to an InP PIC using microstages in a laboratory bench set-up. Voltage was applied to the bimorph actuators across the safe operation range (0-55 V) in steps of 1 V. For each combination of actuator voltages the intensity profile for a number of adjacent waveguides at the remote end of the TriPlex chip was measured using an IR camera, which is sensitive to the 1,550 nm wavelength generated by the InP PIC.

Figure 6 shows the intensity profile of one of the waveguides as a function of actuator voltages applied to the left- and right-side actuator, respectively. A maximum in coupled light can be found for different combinations of actuator



3 Side view of an actuator beam. Only the initial section of the beam is provided with poly-Si, the length of this section determines the initial post-release offset. An offset of ~8 μm needs to be compensated.

4 Examples of fabricated devices.

(a) Configuration consisting of four bimorph actuator beams together with a chevron actuator and lever.

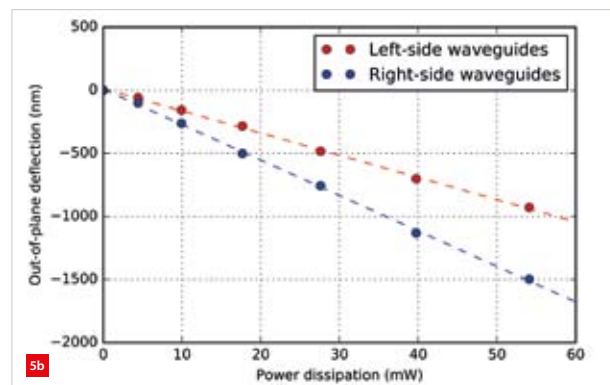
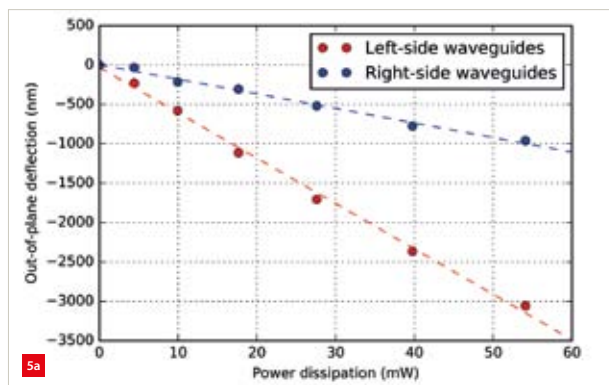
(b) Configuration consisting of six waveguide beams in the centre, and two adjacent sets of bimorph beams.

5 Motion measurements on the chip of Figure 4a.

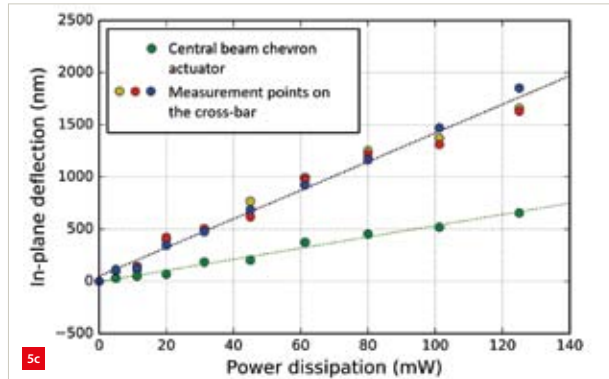
(a) Out-of-plane motion measurement when powering the left-side bimorph actuators.

(b) Out-of-plane motion measurement when powering the right-side bimorph actuators.

(c) In-plane motion measurement when powering the chevron actuator.



6 Result of an optical coupling experiment, showing normalised light intensity of a single waveguide as a function of combinations of bimorph actuator voltages applied to the left-side (L) and right-side (R) actuator set, respectively.

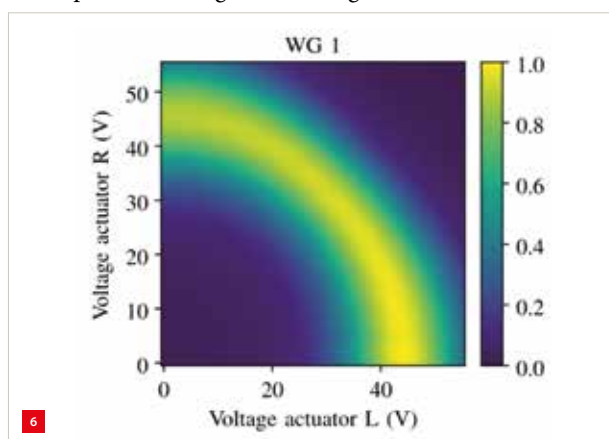


7 PIC with positionable waveguide array and fibre array, bonded to a PCB for testing purposes. (Photo: Hans de Lijser)

voltages. To place the waveguide array in the globally optimal position, the intensity profiles for the individual waveguides need to be combined [9].

Conclusions and outlook

A concept has been proposed for the automated precision alignment of multi-port photonic chips, combining flip-chip bonding and on-chip alignment of flexible waveguide structures. The principles for chip design and fabrication have been explored, and designs are manufacturable which offer alignment capabilities in the three critical motion directions; Figure 7 shows a tangible result: a PIC with positionable waveguide array and fibre array, bonded to a PCB for testing purposes. Further work will focus on optimising the chip design for performance and size reduction. The main function that needs yet to be developed is the integrated locking.



Acknowledgement

Funding for the research leading to these results was received from the STW Generic Technologies for Integrated Photonics (GTIP) programme, grant no. 11355 (Flex-O-Guides), and from the European Community's Seventh Framework Programme FP7/2007-2013 under grant agreement ICT 619267, PHASTFlex. We thank the project partners for their contributions. We specifically thank Tom Scholtes (TU Delft, Else Kooi Laboratory) for microfabrication of the structures in the PHASTFlex project, and Rui Santos (TU Eindhoven) for enabling the optical coupling experiment. ■

REFERENCES

- [1] M. Smit et al., "An introduction to InP-based generic integration technology", *Semiconductor Science and Technology* 29, 083001, 2014.
- [2] T.J. Peters and M. Tichem, "Mechanically flexible waveguide arrays for optical chip-to-chip coupling", *Proc. SPIE 9760, MOEMS and Miniaturized Systems XV*, 97600D, 2016.
- [3] K. Wörhoff et al., "Photonic hybrid assembly through flexible waveguides", *Proc. SPIE 9891, Silicon Photonics and Photonic Integrated Circuits V*, 98911P, 2016.
- [4] PHASTFlex FP7 EU Project, www.phastflex.eu
- [5] K. Wörhoff, R.G. Heideman, A. Leinse and M. Hoekman, "TriPlex: a versatile dielectric photonic platform", *Advanced Optical Technologies* 4, 2015.
- [6] T.J. Peters and M. Tichem, "Electrothermal Actuators for SiO₂ Photonic MEMS", *Micromachines* 7, p. 200, 2016.
- [7] K. Wu and M. Tichem, "In-plane positioning of flexible silicon-dioxide photonic waveguides", *International Conference on Manipulation, Automation and Robotics at Small Scales (MARSS)*, 2017.
- [8] K. Wu and M. Tichem, "Post-release Deformation and Motion Control of Photonic Waveguide Beams by Tuneable Electrothermal Actuators in Thick SiO₂", submitted for publication.
- [9] T.J. Peters and M. Tichem, "On-Chip Positionable Waveguides for Submicrometric Photonic Alignment", *Journal of Microelectromechanical Systems* 26, pp. 1259-1271, 2017.



ADDITIVE MANUFACTURING **MATURING** WITH THE AID OF **PRECISION** ENGINEERING

Once again, Berkeley, California, USA, was the home of ASPE and euspen during their fifth topical meeting, dedicated to advances in applying precision engineering principles to Additive Manufacturing (AM). Conclusion: there is still significant work to be done before AM reaches overall industrial maturity. However, AM is already highly usable for many applications, including precision instrumentation and machine elements.

GERRIT OOSTERHUIS

Setting

The conference days at Berkeley were packed with good quality sessions, alternated with great Berkeley gourmet food and Californian craft brews. A big compliment should go out to the Lawrence Berkeley National lab crew that hosted a flawless event with seamless logistics, regardless of power outages and a failing air conditioning.

As usual, John Taylor and Richard Leach, as conference chairs, were fabulous hosts and really did all they could to make everyone feel welcome. They had put together a good line-up of relevant talks and posters that basically covered the complete process from design to manufacturing [1]. About 150 researchers and engineers for three days discussed advances in applying precision engineering principles to AM.

Conference outline

The conference series is a joint undertaking of ASPE and euspen, the American and European societies for Precision Engineering (and Nanotechnology), respectively. Its driver is that, although being widely used in many different industries, additive manufacturing (AM) has very little determinism in the manufacturing process. There is a lot of trial and error involved in the process development and robust as well as functionally relevant quality parameters are virtually non-existent.

Both chairmen presented their vision on what is needed before AM can be called a precision technology. A lot of published work on AM lacks rigorous uncertainty assessments and thus renders to be mostly qualitative. Hence, any presenter during the conference that would put numbers on the screen could count on the gentle but

determined scrutiny of the team from University of Nottingham, UK, headed by Richard Leach. The Dutch community was well represented with participants from the universities of technology of Delft and Eindhoven and VDL ETG.

Trends

Throughout the conference it became clear that AM is still immature in terms of industrialisation and requires fundamental rethinking of certain qualification methods to allow it to become more industrial. Several of the papers presented investigated improvements to AM machines that seem to be rather obvious from a machine control point of view, yet are poorly implemented in existing machines. Examples are laser beam profile monitoring, feedback control on powder bed piston heights and dedicated laser scanning strategies for lattice structures. In terms of metrology and quality control, measurement and interpretation of surface texture parameters, and the use of X-ray computer tomography (CT) scanning were both discussed extensively in several presentations.

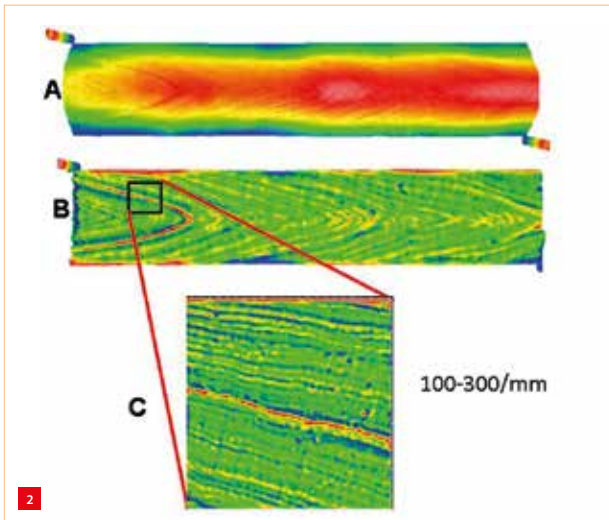
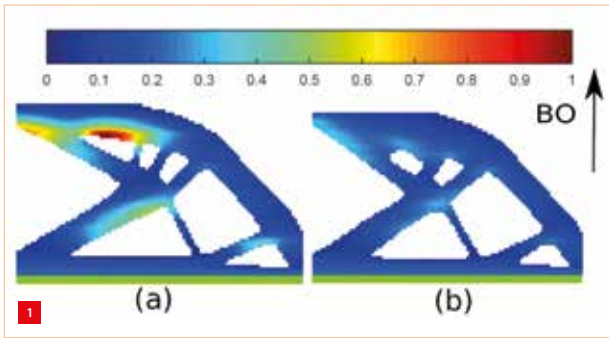
Highlights

The conference started off with the presentation of a great European project, PAM², headed by Ann Witvrouw from KU Leuven, Belgium [2]. The project is an academic collaboration that covers advanced design methods, process modelling and optimisation, in-process quality control and post-machining. Some impressive advances could already be shown. For instance, topology optimisation that besides mechanical properties, also tries to limit excessive heat accumulation during the AM process (Figure 1). In this way automated design can help to generate structures with functional and material properties that are better than when the algorithm applies just geometric design rules.

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Especially impressive were the efforts of University of Nottingham and University of North-Carolina at Charlotte, USA, on extracting in-depth properties of the surface as well as the subsurface defects from topography and CT measurements; see Figure 2. Making these measurements truly quantitative is however still challenging.

New processes were shown that extend the practical application area of metal AM beyond the well-known laser powder bed fusion, towards large scale – wire and arc welding by Gefertec [4] – as well as towards very small scale – micro-powder bed fusion [5] by the Fraunhofer Institute for Laser Technology (ILT); see Figure 3.

Also, advanced characterisation tools for metrology were presented; a novel method by Zeiss stood out which allows

non-destructive 3D grain structure analysis – grain structure is a key differentiator between AM and conventional machining/casting technologies.

Outlook

After the conference, one could leave with the idea that there is still significant work to be done before we see AM reach industrial maturity. However, 'good quality' basically means 'good enough for the intended application' and as such, AM is highly usable for many applications, including precision instrumentation and machine elements.

For example, AM-manufactured flexure hinges can very well be used in semi-static applications, where they can yield greatly improved kinematics and form factors as compared to conventional approaches. However, if there is a need for high cycle fatigue strength, there are some serious limitations. If there is a need for a very predictable or repeatable spring constant or lack of parasitic errors, then maybe AM should be used with caution. It all depends on the tolerances needed to perform the required functions.

The aim of the ASPE/euspen community that contributed to this conference is to expand the application range, by tightening the achievable precision specs of AM parts and specially to make their manufacturing more controlled. It will take a while before AM can be used in single-digit-micron-precision applications. Nevertheless, the newly developed approaches to make the process better controllable and more deterministic are already expanding the applicability of AM in many different industries. ■

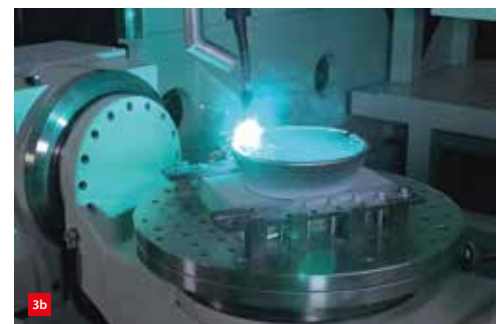
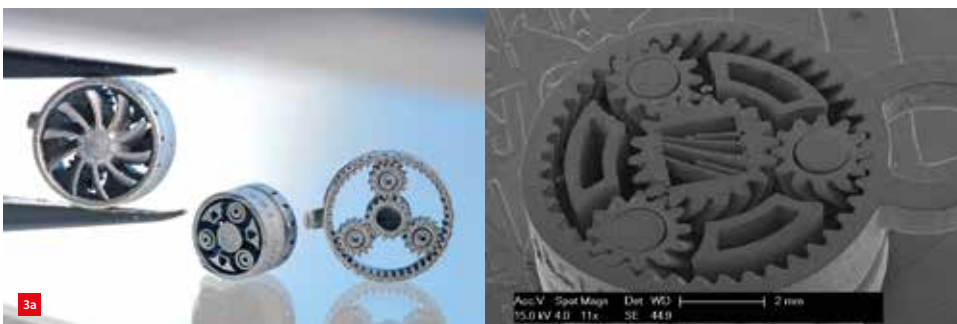
REFERENCES

- [1] www.euspen.eu/events/special-interest-group-meeting-additive-manufacturing-2018
- [2] A. Witvrouw et al., "Precision additive metal manufacturing", ASPE/euspen 2018 Summer topical meeting on Advancing Precision in Additive Manufacturing, 2018.
- [3] Z.C. Reese, J. Fox, J. Taylor and C. Evans, "Evolution of cooling length in parts created through laser powder bed fusion additive manufacturing", ASPE/euspen 2018 Summer topical meeting on Advancing Precision in Additive Manufacturing, 2018.
- [4] www.gefertec.de/en
- [5] L. Masseling and C. Gayer, "Micro-Powder Bed Fusion (μ -PBF) – Extremely high resolution for small-scale applications Laser Powder Bed Fusion", ASPE/euspen 2018 Summer topical meeting on Advancing Precision in Additive Manufacturing, 2018.

1 Normalised temperature fields superimposed on 2D cantilever designs obtained by (a) standard topology optimisation (TO), and (b) hot-spot constrained TO. It can be seen that in case (b) hot spots are eliminated, which in the printing process are a cause for defects and local deformations of the part. BO in the figure signifies the 'build orientation'. (Source: [2])

2 Example of advanced topography data filtering that reveals the spatial frequency of so-called chevron patterns which are related to the thermal history of a laser melting scan track over the powder bed. Being able to reveal and analyse these chevron patterns is a possible way to determine material properties right after melting. (Source: [3])
(a) Unfiltered scan line.
(b) Scan line with cylinder shape removed and a Fourier bandpass filter from 20 per mm up to 100 per mm.
(c) Filter cut-offs adjusted to 100 per mm up to 300 per mm.

3 New AM processes.
(a) Products created by micro-powder bed fusion (μ PBF) by Fraunhofer ILT. (Source: [5])
(b) Wire and arc welding in a 5-axis machining centre by Gefertec. (Source: [4])



TAPPING INTO A NEW DSPE MEMBER'S EXPERTISE

Eltrex Motion – partner in motion control

Eltrex Motion focuses on the motion control technologies market in the Benelux from its offices in Breda (the Netherlands) and Antwerp (Belgium). Its mission is to know and understand the latest motion technology developments, and thereby help customers adapt to tomorrow's demands by finding the best available solutions for their motion challenges. Eltrex Motion offers a complete range of drive and motion technologies, from components to complete systems, as well as services covering engineering, project management, logistics and field support.

Eltrex Motion was founded 1 January, 2014, in a merger between Telerec's Motion Solutions competence team and Eltromat, a company that was acquired in 2011 by the Eight Lakes group, a financially strong and independent group of companies. Eltrex Pro, sister company of Eltrex Motion and part of the same group, specialises in complex motion control projects for the defence, aerospace and security industry.

Team

Eltrex Motion's mission is to assist customers in making their final products more competitive. They do this by advising them on the best-fitting building blocks and innovative drive solutions, and combining motion products from first-class suppliers with state-of-the-art driver technology. This is realised by establishing long-term partnerships with first-class manufacturers in combination with the in-house application of engineering knowledge.

Eltrex Motion has second-to-none product lines available that provide the best-fitting mechanical parts, and it commands the resources to develop and implement the required control software. The dedicated sales team provides customers with a single point of contact and they cooperate closely with their product manager colleagues, who have in-depth knowledge of motion products and markets.

Systems partner

Eltrex Motion not only sells components; it can also act as a fully-fledged systems partner, contributing to the customer's development of applications in not only the automotive, aerospace and food industry, but also in the medical sector and the packaging industry. The company has the necessary knowledge in-house for system integration, product development, production and quality management. For large projects, Eltrex Motion can get customers started quickly with pre-assembled modules, which can be adapted to their specifications. Eltrex Motion



supplies standard solutions, products and systems that allow for small, customer-specific adjustments as well as full customisations.

Services

The engineering team at Eltrex Motion has at its disposal an engineering lab, testing facilities and a workshop to support customers in their motion application development. Eltrex Motion's service offering also includes field support, project management, technical documentation, distribution and logistics expertise, and worldwide logistic support. ■

1 For the application shown here, Eltrex Motion provided one of its customers with a Tetra Compact servo motor (in red) from Motor Power Company.

INFORMATION

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YPN VISIT TO **BOSCH REXROTH**

On 11 July, YPN (DSPE's Young Precision Network) visited Bosch Rexroth in Boxtel, the Netherlands. After a short introduction to Bosch Rexroth and their position in diverse fields such as automotive, industrial applications and consumer applications, two of the key focus areas of the Rexroth group in Boxtel were explained. The first was making (custom) hydraulic cylinders and aggregates, while the second was performing contracted engineering work for a wide range of customers, for example in the motion simulation and offshore industry, using their core products and knowledge.

The YPN party was treated to a presentation by Toine Heesbeen on a motion-compensated gangway for the offshore industry. This gangway is attached to a ship and is able to compensate for the ship's movements relative to the fixed world, such as those that are due to waves or transporting people from the ship to a stationary structure such as a windmill or oil platform. They have also developed a motion-compensated gangway that can compensate for vessel motion during three-metre high swell.

Signals from a motion reference unit are used to calculate setpoints for the three degrees of freedom of the gangway system, i.e. its varying telescoping length, inclination angle and slewing angle. Once the end of the gangway connects to the fixed-world structure, force feedback from the end of the gangway helps to improve the motion compensation. One of the keywords in this Bosch design is redundancy, both in hardware and software, to be able to ensure the safe passage of people at all times.

Next, Johan van Hoof discussed the Pioneering Spirit, the largest construction vessel in the world, which enables single-lift installation

and decommissioning of large oil and gas platforms. The team's design and creativity were put to the test in this project, with demanding requirements such as needing to lift 48,000 tonnes up 4 m within 20 s. This is achieved with the use of 16 parallel levers with dual-stage actuators. The first stage performs relative motion compensation between the fixed world and the ship, comparable to the motion-compensated gangway. The second stage, which is initially decoupled from the lever, is generating the brute power to lift the full oil rig.

After these inspiring presentations, a tour was conducted through the plant for hydraulic cylinder and aggregate manufacturing, together with a demonstration of a driving simulator. The factory tour showcased the different steps in the manufacturing process of hydraulic cylinders. The coating of the rod appears to be of key importance: although currently coatings are often sprayed onto the rods at high velocity, the latest innovation is heading towards laser cladding (overlay welding), which is machined afterwards. The resulting grooves underneath the surface of the piston rods are used in an innovative way by Bosch: while the grooves are not apparent to the human touch and eye, a special measurement system (CIMS) can still detect them. As a result, no additional encoder is required for position and velocity measurement of the (hydraulic) cylinder movement.

About half the group was given the opportunity to experience a six-degrees-of-freedom vehicle simulator with six electromechanically actuated cylinders (using ball-screw spindles actuated by AC brushless motors). One of the key research areas for Bosch is improving the simulation experience to realise maximum immersion in the virtual world. Smart algorithms and special 'poses' of the hexapod can fool the human's vestibular system. For example, a person can lie at such an inclination that they experience sustained acceleration from the force of gravity pulling them into the seat from a standstill position. Bosch has a great deal of knowledge regarding simulation applications for aerospace and vehicles, and they also build simulators with up to nine moving axes, with accelerations of full cars up to 10 m/s², to achieve full immersion. All of which again results in impressive engineering solutions.

The day ended with some networking and a few drinks. YPN would like to thank Bosch Rexroth for their hospitality and the inspiring visit. Particularly, Johan van Hoof for hosting the day, Toine Heesbeen for his talk, Jasper Mandos for the vehicle simulator and Thomas Wintjes for the tour through the factory.

(report by Jordan Bos, Rick Baade and Matthijs van Gastel)

WWW.BOSCHREXROTH.NL



■ The YPN party at Bosch Rexroth.

COURSE (content partner)	ECP ² points	Provider	Starting date
FOUNDATION			
Mechatronics System Design - part 1 (MA)	5	HTI	8 April 2019
Fundamentals of Metrology	4	NPL	to be planned
Mechatronics System Design - part 2 (MA)	5	HTI	29 October 2018
Design Principles	3	MC	13 March 2019
System Architecting (S&SA)	5	HTI	24 September 2018
Design Principles for Precision Engineering (MA)	5	HTI	26 November 2018
Motion Control Tuning (MA)	6	HTI	6 February 2019
ADVANCED			
Metrology and Calibration of Mechatronic Systems (MA)	3	HTI	6 November 2018
Surface Metrology; Instrumentation and Characterisation	3	HUD	to be planned
Actuation and Power Electronics (MA)	3	HTI	20 November 2018
Thermal Effects in Mechatronic Systems (MA)	3	HTI	to be planned (Q2 2019)
Summer school Opto-Mechatronics (DSPE/MA)	5	HTI	-
Dynamics and Modelling (MA)	3	HTI	26 November 2018
Manufacturability	5	LiS	to be planned
Green Belt Design for Six Sigma	4	HI	10 September 2018
RF1 Life Data Analysis and Reliability Testing	3	HI	5 November 2018
SPECIFIC			
Applied Optics (T2Prof)	6.5	HTI	30 October 2018
Advanced Optics	6.5	MC	20 September 2018
Machine Vision for Mechatronic Systems (MA)	2	HTI	to be planned (Q2 2019)
Electronics for Non-Electronic Engineers – Analog (T2Prof)	6	HTI	8 October 2018
Electronics for Non-Electronic Engineers – Digital (T2Prof)	4	HTI	4 February 2019
Modern Optics for Optical Designers (T2Prof)	10	HTI	14 September 2018
Tribology	4	MC	30 October 2018
Basics & Design Principles for Ultra-Clean Vacuum (MA)	4	HTI	20 November 2018
Experimental Techniques in Mechatronics (MA)	3	HTI	to be planned (Q2 2019)
Advanced Motion Control (MA)	5	HTI	5 November 2018
Advanced Feedforward Control (MA)	2	HTI	10 October 2018
Advanced Mechatronic System Design (MA)	6	HTI	26 September 2018
Finite Element Method	5	ENG	in-company
Design for Manufacturing – Design Decision Method	3	SCHOUT	in-company
Precision Engineering Industrial Short Course	5	CRANF	to be planned

ECP² program powered by euspen

The European Certified Precision Engineering Course Program (ECP²) has been developed to meet the demands in the market for continuous professional development and training of post-academic engineers (B.Sc. or M.Sc. with 2-10 years of work experience) within the fields of precision engineering and nanotechnology. They can earn certification points by following selected courses. Once participants have earned a total of 45 points, they will be certified. The ECP² certificate is an industrial standard for professional recognition and acknowledgement of precision engineering-related knowledge and skills, and allows the use of the ECP² title.

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NEWS

Contamination control conference

Contamination control is essential to all high-tech industries and research facilities where 'cleanliness' is a precondition for the quality of the product and for the safety and health of the users or employees. Contamination control enables new technology. New research results and innovative technological applications make it possible to keep improving our control over air purity. Sharing this knowledge worldwide significantly accelerates the developments in this field.

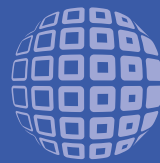
ISCC'18 plays a prominent role in doing so and offers an excellent opportunity to learn all about new applications and inventions concerning the improvement of quality in cleanrooms. ISCC'18 is the International Symposium on Contamination Control and cleanroom technology, which will be hosted by VCCN, the Dutch contamination control society, from 23 to 26 September 2018 in The Hague. The symposium is intended for people that are new in the field of contamination control and for people that are experienced; over 500 participants are expected. The theme of the symposium will be "The world behind Contamination Control" and covers the following areas: Health Care, Life Sciences, Micro-Nano Electronics, Photonics, Micro Assembly, Food, and Space.

Next to the social programme, on the first (Sun)day, there will be a three-day programme consisting of a two-day conference programme with over 60 speakers, divided into 27 speaker sessions. The keynote speakers will be Dave Blank, chief scientific ambassador and professor at University of Twente; Bas Zaat, principal investigator at Amsterdam Medical Center; Vadim Banine, director Defectivity Department at ASML; and Peter Ros, futurologist.

Additionally, there is a tutorial programme (featuring Cleanroom Requirements, Establish Control, Cleanroom Operations, and Demonstrate Control) and a workshop programme. The fourth day is reserved for the technical visits to ASML, ESA/Estec and Philips.



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HIGH TECH INSTITUTE



Optics

Applied optics (AP-OPT)

Professionals who do not design (specify, test) optical systems but are working in optical projects together with optical designers and who want to know more about optical principles and applications.

The course is developed for people with a non-optical background (e.g. electronics, mechanics, chemistry).

A technical BSc/MSc is required. Training methods are lectures, home assignments, an hands-on session, demonstrations, a tour, course notes and a supporting book.

Data: Starts 30 October 2018 (15 weekly afternoons)

Location: Eindhoven

Investment: € 2,650.00 excl. VAT

hightechinstitute.nl/AP-OPT

Dutch Optics Centre joins forces with T2Prof on optics training course

A partnership between TNO, Dutch Optics Centre, Delft University of Technology, High Tech Institute and T2Prof has redesigned the “Applied Optics” training course. This advanced training is scheduled at TNO Delft early 2019. It is tailored to bring engineers with a non-optical background like electronics, mechanics or chemistry up to speed with their optical expert team members.

By learning the ‘optical language’ and understanding the design rules and principles behind optical systems, non-optics engineers are able to collaborate more effectively with their optical expert team members. This makes the whole system engineering team more successful. The training targets at engineers who work in optical systems teams, but don’t design, specify or test the optics.

The course includes eight bi-weekly afternoon and evening sessions. Lessons are a mixture between theory, demonstrations and hands-on sessions. Subjects include electromagnetic waves, geometrical optics, optical aberrations, polarisation and birefringence, diffraction, interference, light sources and lasers, optical measurement and testing, and illumination for optical inspection.

The “Applied Optics” course of T2Prof was originally designed at the request of ASML. It has been organised many times in the Eindhoven area, formerly by Philips Centre for Technical Training and for the last seven years by T2Prof in partnership with High Tech Institute (see also the article on page 8 ff).

The course takes a deep dive in applications from ASML and TNO. The ASML application lecture is on optical lithography and outlines the optics in ASML scanners and describes which optical measures are developed and used to reach extreme optical characteristics. The TNO application lecture covers the Tropomi earth observation instrument of the ESA Sentinel satellite.

Various demonstrations and hands-on sessions will be based on TNO’s internal optical training course and equipment of TNO and TU Delft. The course includes a tour demonstrating how to manufacture optical components and test the resulting quality.



■ The “Applied Optics” training course treats the Tropomi earth observation instrument of the ESA Sentinel satellite (photo). The mission of this satellite is to study climate change and monitor air quality by measuring the composition of the troposphere and stratosphere. For this purpose, the Tropomi instrument contains several spectrometers. (Photo: ESA)

WWW.HIGHTECHINSTITUTE.NL/OPTICS-TNO-DOC

Integrated granite motion systems

Aerotech presents the concept of Integrated Granite Motion (IGM) systems, in which machine components such as bearings, encoders, and drive mechanisms are engineered and are assembled directly on the granite base and bridge structures. Therefore, IGM systems are distinct from traditional stage-on-granite systems where discrete positioning stages and components are used in the system design. Aerotech IGM systems are custom-engineered to fit the unique and specific needs of the customer’s application or process.

IGM systems can be designed with mechanical or air bearings, ball-screw or linear-motor drives, and a variety of feedback elements ranging from encoders to laser interferometers. Additional axes of motion, such as rotary, lift, or piezo stages, or even galvanometer scanners, can be integrated onto the IGM axes.

An IGM system can have higher stiffness than a stage-on-granite solution because it has fewer parts in the structural loop, resulting in higher accuracy and better dynamic performance. It also can be more compact due to the more integrated nature of machine components and granite. This provides for the possibility of smaller Abbe offsets and better machine positioning accuracy. In addition, it is simpler to optimise axis design parameters such as travel length and payload capacity, because each axis of an IGM solution is engineered and built directly into the main granite structure.



WWW.AEROTECH.COM

Faster and easier CMM error mapping

Renishaw's newly launched XM-600 laser measurement system offers enhanced capability to connect directly with Renishaw's range of UCC CMM controllers (UCC = universal CMM controller, CMM = coordinate measuring machine). Using technology developed for the XM-60 multi-axis calibrator, this enables faster and easier error mapping, measuring all six degrees of freedom from a single set-up, in any orientation for linear axes.

XM-600 communicates easily with Renishaw UCC software during the calibration routine to quickly build a complete error map of the CMM. This functionality is supported from within UCC suite V5.4 and onwards, enabling the complete error map of a CMM within half a day.

WWW.RENISHAW.COM/CALIBRATION



“I challenge the customer to really understand the technical need”

As a System Architect at NTS, this is what I do: “I have a variety of challenges. I challenge the customer to really understand the technical need and sketch concepts to think with him. I derive and manage technical requirements with their verification strategy and align with the customer on priorities. The next step is translating this into work packages for the team and ensuring the quality of work. Besides the project activities I give direction to future competence developments, research topics and continuous organizational improvements. The projects require me to use and develop my competences at full, from technical knowledge to communication skills.

The ability to test different roles within the organization complete the pallet of system architecting at NTS. Our know-how on turn key opto-mechtronics systems and series-production drives our customers competitiveness.”

Rens van den Braber, System Architect

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Accelerating your business



Hexapods to a higher level

In response to the demand from industry for more and more versatile and accurate motion control systems, ALIO Industries has just received a US patent on the next-generation Hybrid Hexapod® technology, which outperforms any other hexapod solution in the market, so ALIO claims. "The Hybrid Hexapod® is a game-changer in the field of motion control, and will stimulate innovation as an enabler of next-generation manufacturing processes."

Hexapods have a long history in motion control applications, but in recent years traditional 6-DoF positioning devices (DoF = degree of freedom) have been found wanting when confronted with the industry demand for higher accuracy, improved repeatability, and better geometric performance.

Simply speaking, hexapods are devices where six links or actuators (that extend and retract) join a stationary bottom plate with a top plate that performs coordinated 6-DoF motion. A sample, fixture, sensor, or any device can be mounted on the top plate and can be manipulated to be in any location and orientation in the available range of travel. In complex applications where high-precision, 6-DoF motion is required, a hexapod is the go-to solution due to its compact size and the fact that it is more reliable than serially stacked stages with their inherent stack-up of errors, alignment difficulties, and cable management issues. With the exponential demand across industry for sub-micron levels of miniaturisation and the requirements for process application motion systems that move from micro- to nano-levels of precision, traditional hexapods cannot achieve the desired results. This is due to performance limitations inherent in traditional hexapod designs that require the accurate coordination of the movement of all six axes to accomplish a motion profile, even if the requirement is only for a simple single-axis motion. In addition, the general perception that hexapods exhibit good stiffness compared to serially stacked multi-axis systems, is only justified for the vertical 'z' axis, with weaknesses in the 'xy' plane.

ALIO's Hybrid Hexapod takes a different approach to traditional 6-DoF positioning devices, and exhibits much higher performance at extremely competitive prices. Rather than six independent legs (and twelve connection joints) ALIO's approach combines a precision XY monolithic stage, tripod, and continuous rotation theta-Z axis to provide superior overall performance.

The combination of serial and parallel kinematics at the heart of ALIO's 6-D Nano Precision® stages renders traditional hexapod kinematics obsolete, with orders-of-magnitude improvements in precision, path performance, speed and stiffness, and a larger work envelope with virtually unlimited XY travel, and fully programmable tool centre point locations.

ALIO's Hybrid Hexapod has sub-100 nm 3-dimensional 6-axis Point Precision® repeatability, making it an essential technology for mission-critical applications in the laser processing, optical inspection, photonics, semiconductor, metrology, and medical device sectors, and indeed all micro-machining projects.



WWW.ALIOINDUSTRIES.COM

Hendrik Van Brussel receives euspen Lifetime Achievement Award

During euspen's 18th International Conference and Exhibition in Venice, Italy, Prof. Em. Hendrik Van Brussel (euspen President 2007-2009) received a euspen Lifetime Achievement Award. Lifetime achievement awards are presented by euspen (European Society for Precision Engineering and Nanotechnology) to engineers and scientists who have made outstanding contributions to the development and growth of one or more aspects of the ultra-precision technologies: high-precision engineering, micro-engineering, nanoscience, and nanotechnology.

Van Brussel is a Belgian emeritus professor of mechanical engineering at the Katholieke Universiteit (KU) Leuven. During his entire career – which spans more than 40 years – Van Brussel has been active in a domain that is today called mechatronics, an area where several disciplines overlap: mechanical engineering, electronics and control engineering, and information technology.

He started his career as expert at the Metal Industries Development Centre (MIDC), Bandung, Indonesia, where he also occupied

the post of associate professor at Institut Teknologi Bandung, Bandung, Indonesia (1971-73). Thereafter, he returned to the KU Leuven (where he had studied as a student) to pursue an academic career, becoming full professor in 1980.

He was head of the PMA (Production Engineering, Machine Design and Automation) Division of KU Leuven (1980-93 and 2001-03), and subsequently chairman of the PMA (2003-10). He was also chairman of the Department of Mechanical Engineering (1993-2001), and

project leader of the Interuniversity Attraction Pole Projects on Advanced Mechatronic Systems (Centre of Excellence), from 1987 until 2006.

Apart from his extensive work in cutting dynamics, structural dynamics, Computer-Integrated Manufacture (CIM), and micro and precision engineering, the rest of Van Brussel's work focused on three key areas: robotics, mechatronics, and holonic manufacturing systems (multi-agent systems).

Van Brussel has undertaken pioneering work in robotics research in Belgium and across Europe focused on topics such as active force feedback, methodology for model-based task-specification and control of 'compliant motion' tasks, universal three-finger grippers, and multi-component force-torque sensors.

In the area of mechatronics, Van Brussel developed a design philosophy, aiming at the 'mechatronic compiler' where the mechanical structure and the motion controller are simultaneously optimised, used for designing high-performance machines and machine systems.

When looking at holonic manufacturing, Van Brussel's main achievement is setting up reference architectures and a design methodology for the systems. The Van Brussel-developed PROSA architecture is generally accepted by the international research community as a reference architecture in this discipline.

WWW.KULEUVEN.BE/WIEISWIE/EN/PERSON/00003225

WWW.EUSPEN.EU



■ Hendrik van Brussel in 2009, at the time of his euspen presidency. (Photo: Nicole Minneboo)

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Faulhaber acquires Dimatech

Faulhaber Drive Systems has acquired Dimatech, a Swiss manufacturer of powerful stepper motors based on disc magnet technology. With the integration, Faulhaber expands its portfolio of stepper motors in the higher performance level and thus provides access to new application areas in the textile industry, medical technology, robotics and automation. Dimatech, based in Les Bois in the Swiss canton of Jura, will in future be integrated in and managed from the nearby Faulhaber PRECISTEP site.

WWW.FAULHABER.DE

New fibre alignment system

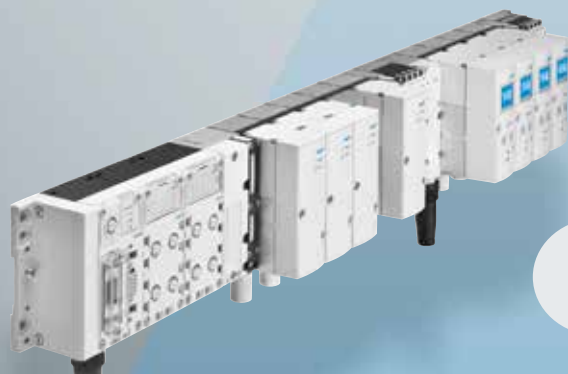
PI presents the F-131 fibre alignment system, ideally suited for alignment of optical components and qualification of optical components in silicon photonics. The basis of the system is an XYZ set-up consisting of three motorised linear stages from PI's M-111 series for rough alignment and a P-611 NanoCube® nanopositioner.

The motorised drives make longer travel ranges possible: rough positioning up to 15 mm, fine positioning up to 100 µm. At the same time, the nanopositioner ensures fast scanning motion and precision positioning; typical resolution is 0.2 nm (open-loop control) or 1 nm (closed-loop). Flexure guides and all-ceramic insulated PICMA® actuators guarantee a long lifetime. Because all drives are equipped with position sensors, it is possible, for example, to reliably prevent collisions with expensive silicon wafers.



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UPCOMING EVENTS

23-26 September 2018, The Hague (NL) ISCC'18

This year, the Netherlands Contamination Control Society VCCN will host the International Symposium on Contamination Control (ISCC), comprising a 2-day conference, workshops, tutorials and technical tours. See also the announcement on page 47.

WWW.ISCC2018.COM

2-5 October 2018, Utrecht (NL) World Of Technology & Science 2018

Four 'worlds' (Automation, Laboratory, Motion & Drives and Electronics) and Industrial Processing will be exhibiting in the Jaarbeurs Utrecht.

WWW.WOTS.NL

8-12 October 2018, Delft (NL) European Optical Society Biennial Meeting 2018

Conference featuring nine topical meetings, including Freeform Optics for Illumination, AR and VR; Optical System Design, Tolerancing, and Manufacturing; Frontiers in Optical Metrology; and Adaptive Optics & Information-driven optical systems.



WWW.MYEOS.ORG/EVENTS/EOSAM2018

10 October 2018, Eindhoven (NL) Software-Centric Systems Conference

Conference devoted to complex software development.

WWW.SOFTWARECENTRICSYSTEMS.COM

11 October 2018, Eindhoven (NL) Smart Systems Summit 2018

A combination of Bits&Chips Smart Systems and DSP Valley's Smart Industry Summit. This year's topics are smart health, smart mobility and technologies for the Internet of Things.

WWW.SMARTSYSTEMSSUMMIT.COM

23-25 October 2018, Stuttgart (DE) Parts2clean 2018

International trade fair for industrial parts and surface cleaning.

WWW.PARTS2CLEAN.COM

4-9 November 2018, Las Vegas (NV, USA) 33th ASPE Annual Meeting

Meeting of the American Society for Precision Engineering, introducing new concepts, processes, equipment, and products while highlighting recent advances in precision measurement, design, control, and fabrication.

WWW.ASPE.NET

12-16 November 2018, Kamakura (JAP) 17th International Conference on Precision Engineering

Topics of the conference, organised by the Japan Society for Precision Engineering, include digital design and manufacturing systems, non-traditional machining and additive manufacturing, robotics and mechatronics, ultra-precision control, nano-scale measurement and calibration, and precision manufacturing education.

WWW.SCOOP-JAPAN.COM/KAIGI/ICPE2018

14-15 November 2018, Veldhoven (NL) Precision Fair 2018

Eighteenth edition of the Benelux premier trade fair and conference on precision engineering, organised by Mikrocentrum.



WWW.PRECISIEBEURS.NL

21 November 2018, Utrecht (NL) Dutch Industrial Suppliers & Customer Awards 2018

Event organised by Link Magazine, with awards for best knowledge supplier and best logistics supplier, and the Best Customer Award.

WWW.LINKMAGAZINE.NL

27-29 November 2018, Paris-Saclay (FR) Special Interest Group Meeting: Structured & Freeform Surfaces

A special focus will be given to research fields in the following topics: replication techniques, structured surfaces to effect function, precision freeform surfaces, large-scale surface structuring, and surfaces for nano-manufacturing and metrology.

WWW.EUSPEN.EU

11-12 December 2018, Amsterdam (NL) International MicroNanoConference 2018

Organ-on-chip, microfluidics, biosensing, and functional surfaces and interfaces are main topics of this industry- and application-oriented conference, exhibition and demo event.



WWW.MICRONANOCONFERENCE.ORG

22-23 January 2019, Sheffield (UK) Integrated Metrology for Precision Manufacturing Conference

The first of two conferences being held as part of a roadmapping project to define the future of integrated metrology in advanced manufacturing in the UK.

WWW.NOTTINGHAM.AC.UK/CONFERENCE/FAC-ENG/METMAP-2019

13-14 March 2019, Veldhoven (NL) RapidPro 2019

The annual event showcasing solutions for prototyping, product development, customization and rapid, low-volume & on-demand production.

WWW.RAPIDPRO.NL

13-14 March 2019, Sheffield (UK) Lamdmap 2019

Thirteenth edition of this event, focused on laser metrology, coordinate measuring machine and machine tool performance.

WWW.LAMDAMAP.COM

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Publication dates 2018

nr.:	deadline:	publication:	theme (with reservation):
5.	21-09-2018	26-10-2018	Big Science (incl. preview Precision Fair 2018)
6.	09-11-2018	14-12-2018	Software / machine learning

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